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TM-2314/000/00

Planning Guide for Computer Program Developmer

10 May 1965

(6) System Development Corp., Santa Monica, Calif.

(9) Technical memo.

(14) Rept. no. TM-2314/000/00

(15) Contract Nonr 4543(00)

TM-2314/000/00

TECHNICAL MEMORANDUM

(TM Series)

This document was produced by SDC in performance of contract Nonr 4543(00)

(6) Planning Guide for Computer Program Development,

Prepared for

Office of Naval Research
Methodology Division

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(11) 10 May 1965,
(12) 119 p.

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A-1180 6/63

FOREWORD

This Planning Guide for computer program development was prepared by the System Development Corporation to fulfill a contract with the Office of Naval Research, Nonr-4543(00). This Guide is intended to be a planning aid for Project Leaders at the Naval Command Systems Support Activity (NAVCOSSACT), particularly during their preparation of Planning Estimates and Project Development Plans. Two preliminary versions (TM-WD-1954/103 and /104) preceded this document, and these are hereby superseded.

The work leading to this Planning Guide is also part of a continuing study of programming management conducted by personnel from SDC's Programming Management Project. The material used in the Guide combines data from the files of the study members and data gathered at NAVCOSSACT. The material and concepts in the Guide reflect contributions from both organizations. Particularly, we wish to acknowledge the assistance and time given by NAVCOSSACT Project Leaders who participated in the early interviews that formed part of the data base for the Guide. Also, we wish to recognize the guidance and contributions of the following NAVCOSSACT personnel: R. Dolan, B. Mandel, J. Salvail, W. Kent, and E. Wolf. Guidance was also provided by J. R. Simpson, Office of Naval Research.

The following SDC personnel participated in the work: B. Nanus, J. N. Wallace, R. S. Steinert, V. LaBolle, N. E. Willmorth, and L. Farr.

ABSTRACT

This document offers a systematic approach for planning projects to develop computer-based information systems. The primary emphasis is placed on the computer program portion of such systems. A descriptive model of the development process forms the basis for a set of prescribed planning and management tasks. The model includes eight phases: (1) System Analysis, (2) System Design, (3) Program Development, (4) Program Coding, (5) Program Checkout, (6) User Documentation, (7) User Training and Assistance, and (8) Turnover. Each phase is further divided into tasks and subtasks for the purpose of more clearly understanding the elements of the development process. A detailed sequence of planning activities provides guidance for planning, scheduling and costing the tasks that comprise the development process, and forms are supplied to record the planning results and to serve as checklists for the required work. The forms and procedures also provide a basis for project control and for collection of data that may be used to improve estimates based upon experience. Although this Guide was prepared for use at the Naval Command Systems Support Activity, the material can easily be adapted to apply to programming in other organizations.

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LIST OF ILLUSTRATIONS

I. INTRODUCTION

This Planning Guide is intended as an aid for managers of automatic data processing (ADP) development efforts. To help a manager plan for development of computer programs, the Guide supplies techniques and advice on how to sequence the work and estimate the costs and schedules. The nature of program development is depicted to identify its influence upon the job of the technical manager. Although the Guide was prepared for use at the Naval Command Systems Support Activity (NAVCOSSACT), the material applies to planning for a much broader spectrum of programming in other organizations.

A. THE SOURCE OF INFORMATION

As a relatively new discipline, computer programming lacks proven, systematic techniques for planning and comparing the planned efforts with completed efforts. On the other hand, considerable experience has been amassed, and this Guide extracts and organizes elements of this accumulated experience. More specifically, the Guide synthesizes analyses of programming experience at NAVCOSSACT and other organizations and divides the programming process into 36 tasks. A generalized example of how to plan for these tasks is given. For example, a Gantt Chart shows the time sequence of the tasks.

B. THE AUDIENCE

The Guide provides advice on how to plan the development of a program system. At NAVCOSSACT, such an effort is known as a Project and is managed by a Project Leader. Therefore, the contents of this Guide are addressed primarily to Project Leaders at NAVCOSSACT and, to the extent that similarities exist in the work of other programming organizations, the remarks are then also addressed to the Project Leader's counterpart. The Guide may well be helpful to other levels of programming management as well as to users and buyers of computer programs.

Although the primary aim is to provide guidelines for planning a programming project, i.e., an effort that results in delivery of a computer program to a customer, the Project Leader will find some of the initial steps useful for both planning and conducting a feasibility study of the proposed effort. As he progresses through the preliminary analysis and design tasks called for in planning, he will recognize the specific requirements and assess the feasibility of meeting them.

C. ORGANIZATION OF THE GUIDE

Some of the organization and the vocabulary used in the Guide reflect current guidance for programming managers within NAVCOSSACT. In addition to interviews and data gathered at NAVCOSSACT, the primary reference is NAVCOSSACT Instruction 5230.1A, Project Management Manual, 17 July 1964. To facilitate the possible use of this Guide in other programming organizations, the various terms, documents, and procedures that are unique to NAVCOSSACT have been explained in the text, particularly in Section II, Background, which provides several kinds of material:

- translation from the NAVCOSSACT framework to a more general environment for computer program development;
- a generalized concept of computer programming to establish a common ground with the reader. Included are some characteristics of computer program development and computer programs as products and their implications for the manager of program development; and
- some additional terminology for NAVCOSSACT readers to help them interpret the advice in the Guide.

Following this background material, Section III, Using the Planning Guide, provides a step-by-step procedure for developing a Project plan. This section introduces the various aids that are contained in the remainder of the document, such as forms for recording planning information.

Section IV provides some specific guidance on how to estimate the various resources and the elapsed time needed for computer program development. It also lists factors that influence computer programming costs and shows their influence on various tasks that constitute program development.

Each of the remaining sections, V through VII, corresponds to one of three broad activities in computer program development at NAVCOSSACT. These activities, labeled Analysis and Design, Program Implementation, and Support and Turnover, are in turn divided into Phases to further describe that particular activity.

ANALYSIS AND DESIGN ACTIVITY

System Analysis Phase
System Design Phase

PROGRAM IMPLEMENTATION ACTIVITY

Program Development Phase
Program Coding Phase
Program Checkout Phase

SUPPORT AND TURNOVER ACTIVITY

User Documentation Phase
User Training and Assistance Phase
Turnover Phase

The sections V through VII are organized alike. First, an introduction outlines and describes the purpose of the broad activity, followed by a review of the work in the Phases, and then typical technical management problems and cost factors are discussed. In addition, the task descriptions that constitute the bulk of each of these sections are previewed. These task descriptions, called Check Sheets, are provided in a format modeled after a typical computer program transfer function. That is, the Check Sheets provide a statement of Inputs, Subtasks, and Outputs for each task. In addition, they include statements about the Environment in which the task will be conducted as well as specific factors that influence the cost of performing this task. For easy reference, each section of the Guide, as well as the Check Sheets for each Phase, have index tabs.

D. MAINTENANCE AND USE OF THE PLANNING GUIDE

Although the Guide is intended principally for planning, the text and forms provide a means for continuous control of a Project. Actual progress on a Project and the corresponding expenditures of time and resources may be compared to plans to determine if changes are needed.

Such changes are "normal" in programming efforts because of the relative absence of systematic, reliable techniques for prediction. Based upon this lack, the themes or the generalized advice for the planner in this Guide are:

- plan in detail,
- review and revise plans frequently, and
- coordinate plans, both new and revised, with support organizations within NAVCOSSACT and with the system user.

To help the planner make numerical estimates, quantitative rules of thumb are given throughout the Guide. Based upon experience, these rules lack rigorous validation under controlled conditions, and the reader is cautioned to temper them with his own judgment and experience when he uses them. Information on the relative success of these rules is supplied when it is available. Use of the Guide and the forms provided is one way to accumulate detailed data to characterize programming experience. After sufficient data have been recorded for many Projects, they may be analyzed to derive quantitative planning factors that could be inserted in modifications of the Guide. An example of results from analysis of this type is shown in Section IV, Guidelines for Estimation.

Since this effort to set down planning principles for computer program development is essentially part of a learning process, the contents of the Guide are subject to change. (The looseleaf format permits pages to be inserted or removed easily.) Such changes may result from:

a. the development of new insight into the programming process,
b. changes in requirements for programs, and
c. advances in technology such as new computers or programming techniques.

II. BACKGROUND

To make the best use of the Planning Guide, the reader should have some understanding of the concepts on which it is based. Therefore, this section presents background material on:

- Some characteristics of computer programs and programming projects, both in general and in particular, at NAVCOSSACT, and
- Some factors that contribute to the difficulty of programming management.

A. ASSUMPTIONS FOR THE PLANNING GUIDE

In preparing this Planning Guide, certain assumptions were made about the development of program systems. These assumptions, some of which are elements of the programming process, management structure, and policy now used at NAVCOSSACT, are as follows:

- The production of a program system should be organized as a Project with a series of Phases (System Analysis, System Design, Program Development, Program Coding, Program Checkout, User Documentation, User Training and Assistance, and Turnover) composed of tasks and subtasks. This model conforms to the way in which program development is organized at NAVCOSSACT and does not differ in any major way from practice in other programming organizations.
- A Project begins with the receipt of a Project Request,* that may be preceded by gross requirement analyses, feasibility studies, and overall system design, and ceases with the acceptance of the system by the customer after a shakedown period.

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*Project Request--a document submitted by a user indicating the objective, the concept of operation, the tasks, the security classification of the desired data-processing capability. The document also calls out the earliest date the capability could be accepted, the latest date for turnover and an optimum date. These Requests trigger the planning process at NAVCOSSACT.

- A programming Project exists in a dynamic environment, requiring that such documents as Project Estimates,* Project Development Plans,** functional descriptions, and other statements of system requirements and program specifications be kept up to date.

- Advice for the Project Leader should be devoted to actual program development, e.g., evaluation and feedback on completed work, shifting forces as tasks prove difficult or easy, etc., rather than being devoted to basic and concurrent supervisorial tasks such as training and personnel evaluation.

- Documentation of programs and programming should be encouraged in intermediate as well as final stages, to:

  a. increase the tangibility of work results;
  b. promote continuity of work;
  c. create a file of program designs, development techniques, test plans, etc., for future use; and
  d. promote continuity of information and its communication in systems following an evolutionary design and implementation plan.

- Review, validation, and inspection of products should be stressed to insure proper performance and compatibility with other systems and products affected by their design and operation.

B. SOME CHARACTERISTICS OF INFORMATION PROCESSING SYSTEMS AND THEIR DEVELOPMENT

Consideration of the nature of information processing systems and their development will help the Project Leader to plan. Projects to develop computer program systems are characterized by the following:

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*Project Estimate--a document prepared by a Project Leader containing estimates of dollar costs, man month costs (contractor and in-house), computer time, a gross schedule (total elapsed time) and NAVCOSSACT rating factors for Project complexity (see NAVCOSSACT Instruction 5230.1A). This early document is used primarily to obtain management agreement to proceed with the Project.

**Project Development Plan--a more detailed forecast dividing the Project work into the eight Phases with schedules and manpower estimates for each. Number of instructions, computer time, and dates for key milestones are estimated. This document is used as a basis for status reports once the Project is underway.

- The products are, by and large, intangible. That is, they are procedures and algorithms, ideas and concepts, organizations and flows, efficiencies and optimizations rather than hardware.

- The products are intimately related to the operations, and mode of operation, of the system user.

- The user, in many cases, may not have a clear idea of precisely what he needs when a Project begins, may be unable to communicate the need to program developers, or may be reluctant to release the information for security or proprietary reasons.

- Program system products and programming processes are subject to frequent change.

- A program system typically takes a long time to design and produce, and consequently suffers from loss of information through obsolescence and turnover of personnel.

These characteristics are the sources of many problems inherent in the development of program systems:

- The intangibility of programs and procedures makes it difficult to evaluate the product that has been produced.

- Ambiguity in specifications makes comparison of systems and system features indecisive and leads to disagreements over whether the product really satisfies stated requirements and specifications.

- Ambiguity in statements of work leads to the failure to recognize the importance of individual tasks and the impact that poor performance in a task may have upon others.

- Intangibility and ambiguity result in overemphasis upon tasks that lead to visible "hard" products and underestimation of the difficulty and cost of less tangible tasks such as "supervise," "coordinate," and "evaluate."

One way to resolve uncertainty and to provide tangible products for programming activities is through documentation. Some tasks have documentation built into them ("develop tests," "flowchart," "specify"), and others may be designated as documentation tasks by requiring reports ("produce user documentation"). The number of different types of documents usually depends upon user needs and the policy and work procedures in the programming organization. How much documentation a Project will require depends upon its complexity, size, duration, and changeability, and is partially determined by the individual Project Leader. Although a theme in this Planning Guide is thorough, accurate, and up-to-date documentation during program development, the danger of developing large amounts of expensive, useless documentation exists. Therefore, managers must determine the usefulness of various document types and their content; but, in general, too little documentation is the problem in programming rather than too much.

C. CHARACTERISTICS OF COMPUTER PROGRAMMING PROJECTS AT NAVCOSSACT

The sequence of work to develop a computer program may be divided and labeled in different ways. But, when these various descriptions are examined in detail, they are quite similar. Chart I is a model in block diagram form of the computer program development process as it is viewed at NAVCOSSACT and described in this Guide. The diagram illustrates three major Activities: Analysis and Design, Program Implementation, and Support and Turnover. Within these broad areas are the specific subordinate activities that constitute the process. The subordinate activities are known as Phases, at NAVCOSSACT, and are so termed in this Guide. The Phases are grouped within the major Activities as follows:

1. Analysis and Design Activity

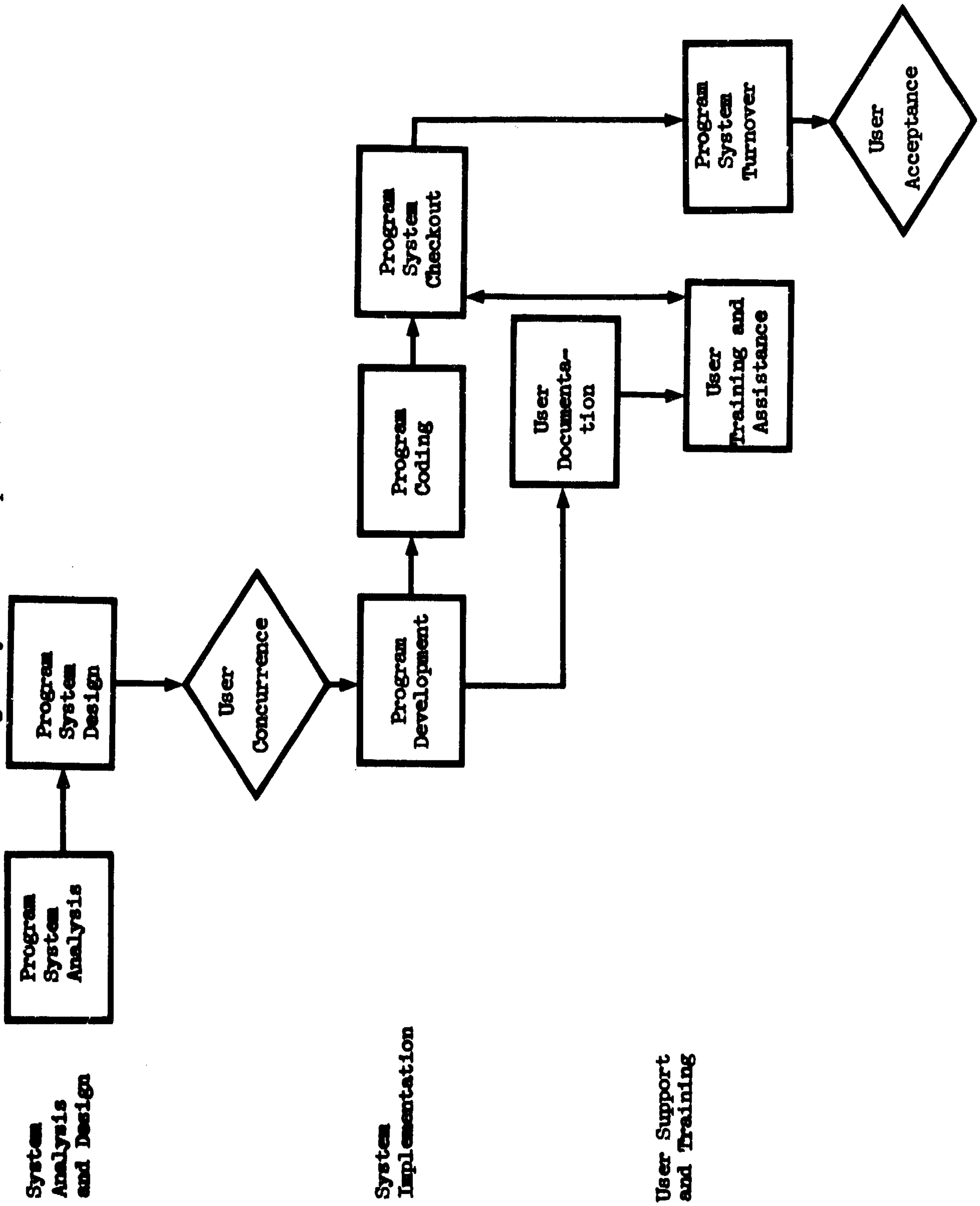
- System Analysis Phase--the investigation of an information processing problem, particularly the need for a new ADP system or a change to an existing one and the conditions that may surround the development.
- System Design Phase--the creation of a scheme, or ADP design, to satisfy the requirements of the user.

At NAVCOSSACT, this Activity also includes the Requirements and Feasibility Studies.

2. Program Implementation Activity

- Program Development Phase--the actual design of the programs, program system test, and program and system files.
- Coding Phase--the production of computer instructions to implement the program designs.
- Checkout Phase--the inspection and test of the coded programs to insure that they satisfy both design specifications and operational requirements.

Chart I. The Program System Development Process



3. Support and Turnover Activity

- User Documentation Phase--the ongoing documentation of the system, in the form of manuals or reports, and the preparation of formal documentation.

- User Training and Assistance Phase--planning for and assistance in the indoctrination of the user into the use of the system. This Phase also includes the collection and conversion of system data, which at NAVCOSSACT is a user responsibility.

- Turnover Phase--the turnover of the program system to the customer and the shakedown of the programs in their operational environment. This work is shared with the customer, but NAVCOSSACT assumes the major responsibility. The word "Phase" implies a time sequence of these types of work. In general, this is true for the process of program system development, but some Phases, such as User Documentation, require continual work during the entire process. In some sense the time-sequence connotation of the word "Phase" still applies, since the time roughly indicated for this Phase would be a period of increased intensity for documentation.

Within, or supporting these broader Phases, many other major efforts may be needed, such as:

- The production of utility and support programs.

- The development of using and operating procedures.

- The conduct of simulation studies.

D. CHARACTERISTICS AND TRENDS OF PROGRAMMING AT NAVCOSSACT

During preparation of this Guide, certain characteristics and trends were noted at NAVCOSSACT. To some extent, these are not unique to that organization, but reflect patterns of growth in other programming organizations (particularly in the government), as well as general trends in automatic data processing.

1. Characteristics

- Program development only part of the total activity. Although program development is the central core of the work, other significant resource-consuming activities are also carried out. Thus, at NAVCOSSACT, the term "Project" refers to many efforts besides program development, e.g., operation of the Navy Information Center (NAVIC) computer and research and development work on programming standards.

- A diversity of users. Requests for programs come from many widely dispersed sources.

- A large number of small Projects. Most efforts appear to be small, in terms of machine-language instructions (e.g., less than fifteen thousand) and number of persons involved (e.g., less than twenty).

- A growing organization with a division of the labor force. Continuing growth results in a shortage of trained personnel. In government organizations such as NAVCOSSACT, the labor force may consist of a mixture of contractor personnel, Civil Service personnel, and military personnel. Also, at NAVCOSSACT, reliance on outside help has caused Project Leaders to act as monitors of contracted Projects.

- A fixed array of computers. The basic computers now and for the near future are relatively fixed, e.g., at NAVCOSSACT, the basic computers are the IBM 1401, IBM 7090, AN/FSQ-20, CDC 1604 and CDC 160 (or models of them).

- Many reprogramming efforts. Many programming efforts require one data-processing capability at one operational center to be adapted to serve another center and/or the conversion of programs from one machine to another.

- Many revisions of existing programs. Feedback from users and changes in procedures demand modifications to existing programs.

- A "service bureau" policy. To provide program and development services to a large number of users, the organization must try to preserve its resources. To bound the ADP development process, an organization such as NAVCOSSACT defines maintenance as a user responsibility. Also, as indicated earlier, the extent of NAVCOSSACT participation during development is bounded; e.g., the user is primarily responsible for a potentially significant task--Data Collection and Conversion.

2. Trends

- A reduction in software diversity. Despite the rapid expansion of ADP into many new fields, programming languages and tools and application programs have tended toward a common information-processing technology that cuts across areas of application. As a result, the stockpile of standard programs and programming techniques grows, and more work can be done to satisfy the need to transfer programs from center to center and convert programs from one machine to another. For example, NAVCOSSACT has used similar programs at more than one center and has standardized with a single programming language.

- A growing adaptability to change. Programming techniques that permit more generality and flexibility are being developed to ease the accommodation of change. For example, at NAVCOSSACT, the data base has been "divorced" from the programs to permit quick changes to it.

- A trend toward integrated systems. Although many applications still call for independent programs and will undoubtedly do so for some time, there is a trend toward integrating computers and program systems into operations. For example, even independent programs must operate under executive program control and communicate with centralized data base structures. With increasing use of computers on-line via data links, communication networks, and multiprocessors, an increasing number of multipurpose, multiservice, multiuser centers may be expected, with increasing demands on programming organizations such as NAVCOSSACT for tightly integrated computer programs to operate within these centers.

- A continued growth of ADP. The actual and projected use of automatic data processing continues to grow in all areas of operations. For NAVCOSSACT this has meant a growing number of Project Requests that, combined with the shortage of available resources, leads to the use of a priority system and the "mothballing" of low-priority projects for short periods of time.

E. COMMUNICATION AND COORDINATION IN TECHNICAL MANAGEMENT

The preceding material provides some background on the process and the products of programming. In this brief discussion, the Project Leader's job is examined, particularly in terms of how it intersects with the more elusive aspects of programming that do not yield hard products.

The uncertain operating environment of computer program development needs extensive and intensive communication, coordination, and control. The Project Leader must actively seek information, encourage and provide coordination and communication, and solicit feedback on every decision. Documentation appears again as a prime tool to promote feedback and verify information as well as to record and transfer experience and information.

In a job characterized by continual change, few standards, and fewer techniques for estimating costs, control is particularly difficult. The Project Leader cannot specify exactly what is to be produced, or precisely what must be done; as a result, he cannot easily evaluate completed work. Nevertheless, he must establish some mechanism for insuring that everything is done that should be, and that things that are not essential are not. Further, he needs a way to control, or at least to know about, all changes. Precise documentation, extensive personal attention, and insistence upon coordination and concurrence procedures for all designs, procedures, and changes thereto are his management techniques.

The Project Leader must be aware of, integrate and coordinate major interactions or interdependencies among the following:

- Tasks--the processes necessary to produce the system. Failure to recognize the importance of the individual tasks and their impacts upon one another is common and invariably leads to slipped schedules and degraded products.

- Organizations--the people and agencies who are banded together to produce and use the system--the customers and the hardware and software developers. Although cost of the program system may be only a small part of the total system cost, the success of the entire system depends upon an effective program system. Program design and operation reflect (1) the design of equipment such as the computer, communication devices, and weapons, and (2) the information-processing policies and procedures in the using organization and others with which the program system interfaces. These design dependencies demand coordination contacts by the Project with equipment developers, using organizations, and interfacing organizations. Face-to-face interchange must supplement documents to overcome the language barrier that often exists between user or equipment development personnel and system analysts in the Project.

- Products--the programs themselves and their corresponding documents. In using ADP, part of the trend toward integration of information processing using computers, computer programs, and communication equipment, particularly integration of many centers with on-line use of computers, is increased program system size and complexity. Interaction among programs in a program system is a factor frequently overlooked or underestimated in Project planning and costing. Such interactions call for increased coordination and communication between programmers working upon the individual programs that interface. Increased work for analysis and design is also needed, as well as the additional code to handle the communications among programs. In large, complex programs, this part of the program system for functions such as control and housekeeping may be a high percentage of the total code. Finally, larger, longer, and hence more expensive tests are needed to check out programs, subsystems, and the total program system.

F. TERMINOLOGY

This Planning Guide uses many of the technical and managerial terms in the NAVCOSSACT Project Leader's Guide (NAVCOSSACT Instruction 5230.1A). In addition, the following common terms not defined in the reference are defined here for all readers:

- Routine--a section of code (computer instructions) in a program that performs some identifiable function and that is organized and identified as a logical entity.

- Program--a set of one or more routines or sections of code that perform some identifiable function or set of functions and are organized to operate as a self-contained unit.

- Program Subsystem--a set or subset of one or more functionally interdependent programs that operate together to perform a more or less self-contained data-processing task or phase within a larger system of program or other system components.

- Program System--an interrelated set of one or more programs or program subsystems that perform the automatic data-processing functions of a system and are identified as belonging to the set. Routines, subsystems, and systems often relate to one another, through the operation of a control or executive routine, program, or subsystem.

- Program Test--the application of a set of data and procedures to a program to assure the developers that the program will operate as specified (also known as a parameter test and "debugging").

- Program Subsystem Test--a test of a subsystem to insure correct communication between the various interdependent programs that comprise the subsystems.

- Program System Test--a program test applied to a total system of programs, often, but not necessarily, in a live environment, using "live" data (data generated during the actual operation of the system) to assure that various programs interact as specified and required, to determine if operational requirements for information processing are satisfied, and to evaluate ease of use and maintenance.

- Program System Data Base--central data files, excluding tables and constants that are used only by individual programs and so are not stored centrally.

Following these background remarks on the nature of program development, its characteristic problems, and the more difficult parts of a Project Leader's job, Section III provides a recommended procedure that outlines, step by step, how to use this Guide to plan a programming Project.

III. USING THE PLANNING GUIDE

A. PLANNING A PROJECT

The objectives of Project planning are (1) to state, in some detail, the intermediate and final products of the Project, the work needed to develop these products and the expected conditions under which the work will be done, and (2) to estimate the kinds of resources needed and their costs in terms of elapsed time, manpower, and machine hours.

To plan a Project, in addition to specific knowledge of the job to be done, the Project Leader must know, in general, what to plan for, what sources of information he has, what aids he has to help him plan, and what procedures he should follow in planning. To help meet these needs, the Planning Guide (1) describes the contents of plans in terms of schedules, cost estimates, and product lists, (2) suggests sources of planning information, and (3) presents in this section some planning aids, e.g., forms, and a procedure for planning.

B. THE OUTPUTS OF PLANNING

The planning procedure outlined below carries planning for a programming project from its inception to the point where a detailed plan exists for the production of a system. As mentioned earlier, well-defined procedures do not exist for formulating an effective plan by using only a statement of requirements. The absence of such techniques means that to develop a plan, work must be done to define or analyze the particular information processing problem and even some work must be done to design programs that solve the problem. In addition to its contribution to planning, work of this type constitutes the first activity in program development, i.e., System Analysis and Design. Generally this work proceeds in iterative stages--first analysis then design--in which the detail increases and various alternatives are rejected at various decision points. At NAVCOSSACT, three major decision points and allied products are identified: first, a gross estimate of system feasibility and overall costs; second, an estimate of more detailed system requirements and a plan for system development; and, third, a detailed design for the system and a plan to produce it. Planning does not stop at this point; a Project Leader must take many more plans to detail the actions of his Project, and the existing plans, always subject to change, must be maintained. The issuance of these plans, however, may result in a management action to cease planning and development at any of these major decision points. At NAVCOSSACT these plans mark the following decisions:

1. Planning Estimate

As a result of a preliminary analysis of the Project Request and the work expected, the decisions that might be made are:

- The system implied is desirable and technically and economically feasible and, tentatively, can be developed using internal resources. A rough estimate of Project duration and cost is made and more detailed analyses of requirements are undertaken. At NAVCOSSACT, this statement, called the Planning Estimate, must be prepared within 60 days following receipt of the Project Request.

- The system is feasible, but cannot be produced with the available internal resources. Both the Planning Estimate and a more detailed analysis of requirements are used to prepare a statement of work and a request for proposal by an outside contractor.

- The system is not feasible. A report of nonfeasibility is sent to the system requestor and the planning ceases.

2. Project Development Plan

As a result of more detailed analyses, a gross inventory of system requirements, functions, and environment is generated, and either the Project Leader or the selected contractor prepares a Project Development Plan that presents:

- A gross estimate of system development and implementation requirements.

- A preliminary flow diagram for the system.

- A tentative schedule for the Project.

- A tentative estimate of the manpower and computing time required to produce the system.

On the basis of this more detailed analysis, the decisions to be made are:

- The system is technically and economically feasible and desirable and planning should continue. If appropriate, a contract is let.

- The system is not feasible or desirable and development and planning should cease.

3. Project Implementation Plan

As a result of the completion of the System Analysis and Design activities, a set of detailed plans for the production of the system is made including:

. Specifications of system requirements.

. Specifications of the system design.

. Evaluation of system implementation requirements.

. Schedules for system production.

. Cost estimates for system components and system production tasks.

On the basis of these, it is decided that:

. The proposed system design and implementation plan are satisfactory and the implementation of the system is initiated.

. The proposed plans are not satisfactory, but may be modified until they are acceptable.

. The proposed plans cannot be made satisfactory and development and planning should cease.

C. INPUTS AND AIDS TO PLANNING

The planning procedure assumes that the Project Leader has the following aids:

1. A Project Request

A customer's statement of need and requirements that contains a general description of the system to be planned and the problems it must solve for the customer; the statement includes the user's indication of objective, operational concept, tasks, and security classification of the desired data-processing capability. The document also states the dates of earliest acceptance and latest turnover.

2. A Model of the Program Development Process

Sections V, VI, and VII of this Planning Guide contain Check Sheets that describe, a model of the program system development process, in terms of inputs, tasks and subtasks, expected outputs, and environmental factors. The process has been divided into a hierarchy--three activities consisting of eight phases, each divided into tasks and these in turn divided into subtasks.

3. A Project Summary Sheet*

Charts II and III present a suggested form for recording Project planning information as it is derived. One section of the form is used to record general descriptive information about the Project--its identification, its description, its environment, its operating conditions, its size, and various assumptions concerning the production of the system. The second section of the form is used to record the time and cost estimates that are made for each of the major tasks and phases of the program system development for the particular Project.

4. A Computer Program Planning Sheet*

Charts IV and V present suggested forms to assist in the detailed costing of designing, coding, and checking out individual computer programs, as well as an integrated set of these that constitute a system. The form shown in Chart IV is divided first into three parts--Program Development, Program Coding, and Program Checkout--that represent the major products and activities in the production of a program. Each subpart is divided into a description of the product or activity, and a series of major tasks to be performed in producing each product. Information derived using this form for each program comprising the Program System is totaled and summarized on the Project Summary Sheet. For large program systems, several programs may be tested together prior to test of the total system. Chart V, Program System Planning Sheet, is a form for recording planning information for program subsystem and system checkout.

5. Access to Previous Experience

Much of the analysis and costing of a program system will benefit from experiences with similar systems and programs. Because costing and scheduling of computer programs are presently subject to large errors, access to and use of such experience in planning will usually result in more accurate estimates. Sources of such information are the personal experiences of the Project Leader and his colleagues (such as other Project Leaders and Project members), files of previous and current Projects, summary descriptions and evaluations of completed Projects, technical journals and books, and documentation of Projects from other organizations (e.g., technical reports, plans, schedules, and actual costs and experiences in producing the system).

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*Large copies of these forms, suitable for actual use, are included at the end of the Planning Guide.

Chart II. Sample Project Summary Sheet (Page 1)

PROJECT SUMMARY SHEET

PROJECT IDENTIFICATION

REQUEST CODE	DATE	REQUEST TITLE		REQUESTING ORGANIZATION		REFERENCES REQUESTING LETTER	PREPARED BY ____
DIVISION		PROJECT LEADER	DATE ASS D.	CONTRACTOR	CONTRACT DATE	OTHER	REVIEWED BY ____ APPROVED BY ____

PROJECT DESCRIPTION

MISSION AND OBJECTIVES

USING ORGANIZATIONS AND PLACEMENT

PRIMARY FUNCTIONS

SYSTEM ENVIRONMENT

SYSTEM NAME	PROJECT NO.	USING ORGANIZATION	NATURE OF APPLICATION
1. EMBEDDING SYSTEMS			
2. INTERFACING SYSTEMS			
3. SIMILAR SYSTEMS			

MANNING ASSUMPTIONS KEY PERSONNEL	LEAD TIME ASSUMPTIONS	CONTACTS
		USER
		CONTRACTOR
		EQUIPMENT
		OTHER

COMPUTER USAGE

COMPUTER	LOCATION	OPERATING SYSTEM	LANGUAGE	DATE OF FIRST USE	TOTAL HOURS EST	TOTAL HOURS ACT	MAXIMUM USAGE HRS/DAY	MAXIMUM USAGE HRS/WEEK	MAXIMUM USAGE HRS/PERSON	TURNAROUND TIME	COMMENTS

NUMBER OF COMPUTER INSTRUCTIONS

FIRST ESTIMATE (PE RELEASE)	SECOND ESTIMATE (PDP RELEASE)	THIRD ESTIMATE (PFD RELEASE)	ACTUAL (SOURCE LANGUAGE)	ACTUAL (MACHINE LANGUAGE)

Chart III. Sample Project Summary Sheet (Page 2)

PROJECT SUMMARY SHEET
(PAGE 2)

PROJECT PHASES & TASKS	NUMBER OF MAN MONTHS			START DATE			COMPLETION DATE			NUMBER OF COMPUTER HRS.		PROPOSED MANNING				REMARKS (DATES AND REASONS FOR REVISIONS, ETC.)
	EST	REV EST	ACT	EST	REV EST	ACT	EST	REV EST	ACT	EST	ACT	SR. ANAL	ANAL	SR. PROG	PROG	
SYSTEM ANALYSIS																
1. PLAN THE PROJECT																
2. ANALYZE SYSTEM REQUIREMENTS																
3. ANALYZE USER ENVIRONMENT																
4. ANALYZE PRODUCTION REQUIREMENTS																
5. ANALYZE SIMILAR SYSTEMS																
6. EVALUATE CONTRACT PROPOSALS																
7. ANALYZE CHANGE REQUESTS																
SYSTEM DESIGN																
1. DESIGN TOTAL SYSTEM																
2. DESIGN PROGRAM SYSTEM																
3. OUTLINE PRELIMINARY FUNCTIONAL DESCR.																
4. PRODUCE PRELIMINARY FUNCTIONAL DESCR.																
5. FAMILIARIZE USER																
6. OBTAIN PFD CONCURRENCE																
7. INDOCTRINATE PRODUCTION PERSONNEL																
	★		★		★		★		★				★		★	
PROGRAM DEVELOPMENT																
1. DESIGN PROGRAM SYSTEM TEST																
2. DESIGN PROGRAMS																
3. DESIGN PROGRAM FILES																
4. ESTABLISH SYSTEM FILES																
PROGRAM CODING																
1. CODE PROGRAMS																
2. DESK CHECK PROGRAMS																
PROGRAM CHECKOUT																
1. LEARN TEST ENVIRONMENT																
2. COMPILE AND CHECK CODE																
3. TEST PROGRAMS																
4. TEST SUBSYSTEMS																
5. TEST SYSTEM																
USER DOCUMENTATION																
1. VERIFY SPECIFICATION DOCUMENTATION																
2. OUTLINE USER DOCUMENTATION																
3. PRODUCE USER DOCUMENTATION																
4. OBTAIN CONCURRENCE																
5. PUBLISH USER DOCUMENTATION																
USER TRAINING AND ASSISTANCE																
1. DATA COLLECTION AND CONVERSION																
2. DEVELOP USER TRAINING PLAN																
3. PROVIDE USER TRAINING AND ASSISTANCE																
TURNOVER																
1. DEVELOP TURNOVER PLAN																
2. CONDUCT DEMONSTRATION																
3. OPERATIONAL SHAKEDOWN																
TOTALS																

★ PHASES ABOVE THIS LINE WILL BE COMPLETED AFTER PLANNING ESTIMATE IS APPROVED.

PHASES BELOW THIS LINE WILL BE COMPLETED AFTER PRELIMINARY FUNCTIONAL DESCRIPTION IS APPROVED.

Chart IV. Sample Computer Program Planning Sheet

COMPUTER PROGRAM PLANNING SHEET

PROGRAM IDENTIFICATION	PROGRAM NAME	PROGRAM FUNCTION	TYPE JOB (NEW, CONVERSION, REV.)

PROGRAM DEVELOPMENT

PROGRAM DESIGN	MAN MONTHS			START DATE			END DATE			ASSIGNMENTS	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	FIRST	SECOND
LOGIC ANALYSIS & FLOW CHART											
TIMING ANALYSIS											
DESIGN REVIEW											
PROGRAM SPECIFICATIONS						ELAPSED TIME					
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 2											

DATA DESCRIPTION	NUMBER OF ITEMS			INPUT FORMATS			OUTPUT FORMATS			NUMBER OF TABLES			NO. OF CONSTANTS & PARAMETERS			NUMBER OF FILES		
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL

DATA DESIGN	MAN MONTHS			START DATE			END DATE			ASSIGNMENTS	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	FIRST	SECOND
DATA ANALYSIS											
I/O FORMATS											
DATA DESIGN											
ALLOCATE STORAGE											
DATA REVIEW											
DOCUMENTATION						ELAPSED TIME					
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 2											

PROGRAM DESCRIPTION	NUMBER OF INSTRUCTIONS						NUMBER OF BLOCKS			COMPLEXITY			NUMBER OF LIBRARY ROUTINES			NUMBER PAGES OF DOCUMENTS		
	NEW			REVISED														
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL
ENTER TOTAL NUMBER OF INSTRUCTIONS ON SUMMARY SHEET																		

PROGRAM CODING

CODING DESCRIPTION	NEW ROUTINES			REVISED ROUTINES			LIBRARY ROUTINES				NUMBER PAGES OF DOCUMENTS		
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL		EST	REV EST	ACTUAL

CODING	MAN MONTHS			KEY PUNCH & VERIFY MACH. HRS.			START DATE			END DATE			ASSIGNMENTS	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	FIRST	SECOND
CODE														
DESK CHECK														
DOCUMENT									ELAPSED TIME					
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CODING TASK 1 AND 2														

PROGRAM CHECKOUT

CHECKOUT DESCRIPTION	NUMBER COMPILE ASSY.			NUMBER CODE CHECKS			NUMBER OF PROGRAM TESTS						NUMBER PAGES OF DOCUMENTS			
							TESTS			TRIALS						
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	

	MAN MONTHS			START DATE			COMPLETION DATE			NO. OF COMPUTER HRS.		ASSIGNMENTS
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	
COMPILE AND CHECK CODE												
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 2												
DESIGN PROGRAM TEST												
TEST DATA PRODUCTION												
TEST PROGRAM												
TOTAL AND ENTER ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 3												

REMARKS

PREPARED BY	REVIEWED BY	APPROVED BY

Chart V. Sample Program System Planning Sheet

PROGRAM SYSTEM PLANNING SHEET

SYSTEM CHECKOUT DESCRIPTION	NUMBER OF SUBSYSTEM TESTS						NUMBER OF SYSTEM TESTS					
	TESTS			TRIALS			TESTS			TRIALS		
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL

PROGRAM SUBSYSTEM TESTS	MAN MONTHS			START DATE			COMPLETION DATE			NO. OF COMPUTER HRS.		NO. PAGES OF DOC.		ASSIGNMENTS
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	ACTUAL	EST	ACTUAL	
DESIGN SUBSYSTEM TEST														
TEST DATA PRODUCTION														
TEST SUBSYSTEM														
TOTAL AND ENTER ON SUMMARY SHEET, PROGRAM CHECKOUT, TASK 4					ELAPSED TIME									

PROGRAM SYSTEM TESTS														
DESIGN SYSTEM TEST														
TEST DATA PRODUCTION														
TEST PROGRAM SYSTEM														
TOTAL AND ENTER ON SUMMARY SHEET, PROGRAM CHECKOUT, TASK 5					ELAPSED TIME									

REMARKS

PREPARED BY	REVIEWED BY	APPROVED BY

6. Intermediate Products of System Analysis and Design

As the Project progresses, it produces much information that is relevant to Project planning. The processes of system analysis and design produce analysis of user's requirements and environment, program requirements and data environment, production requirements and environment, and design specifications for the system, for programs, and for file and data structures, plus many less formal products such as trip reports, conference reports, correspondence, and other documents.

7. Planning Instructions

The Project Leader's management must specify how the leader is to plan. It should specify how the leader and his organization must interface with others, what reports are to be made, what forms must be completed and sent out, and what his other responsibilities and commitments are. At NAVCOSSACT, the Project Leader's Guide (NAVCOSSACT Instruction 5230.1A) and this Planning Guide provide general instructions on the way Projects are to be planned.

D. THE PLANNING PROCESS

The planning process recommended is detailed in this section of the Planning Guide. The sequence of steps outlined tells how to use the Check Sheets contained in Sections V, VI, and VII; explains how to complete the Project Summary Sheets, the Computer Program Planning Sheet and the Program System Planning Sheet; and describes the other activities and products produced in the planning process. This process is assumed to occur over a period of time during which work on the Project proceeds. Therefore, the planner will find that the sequence of planning steps includes or is intermingled with much of the work described in Section V, The System Analysis and Design, and in the Check Sheets for these Phases.

The sequence of the principal planning tasks detailed below is:

1. Preliminary Analysis
2. Information Collection
3. Gross System Analysis
4. Preliminary Program System Design
5. Determination of Work Tasks
6. Schedule Estimation
7. Preliminary Review
8. Obtain Concurrence

PLANNING TASK 1. PRELIMINARY ANALYSIS

Evaluate available information to determine how much more information must be collected, estimate the cost required to collect and analyze it, and make a gross estimate of system size and implementation costs.

The steps to be taken are:

Step 1. Begin to complete the Project Summary Sheet (using the form provided at the end of the Guide) by recording the Project Identification from the Project Request:

- Request code and date
- Request title
- Requesting organization
- Requesting letter reference number
- Division assigned responsibility for the Project
- Project Leader's name and date assigned
- Contractor and contract date

Step 2. Obtain, in addition to the actual Project Request, other information, such as:

- Requirements for the proposed computer program system.
- Proposed information processing, e.g., logistics planning or weapons control that will use the program system.
- User's environment (present as well as future) including mission statements, organization charts, physical location of facilities, operational functions, and mode of operation.
- Proposed system hardware including the computer, input and output equipment, and communications networks.
- Requirements for tests, inspections and/or demonstrations of the system.
- Location and availability of the computer to be used during development.
- The names and descriptions of hardware components that may interact with the program system.

- The number and locations of stations and organizations that will use or participate in developing the system.

Record on the Project Summary Sheet the <u>Project Description</u>:

- Statements of the missions and objectives of the system.
- Description of the using organization and the placement of the program system within its operation.
- The primary functions the system is to perform.

Record on the Project Summary Sheet the <u>System Environment</u>:

- The names of "super" (or larger) systems that include this system as part of their functioning.
- The names of systems that interface with this system, feeding information to it or receiving information from it.
- The names of similar systems that have been developed by NAVCOSSACT or others.

Step 3. Determine and list, briefly, the information that is at hand and that must be obtained. Estimate the effort to collect the required information, and, consequently, the costs of performing the first five tasks of System Analysis as described in the Check Sheets. These estimates are to be entered on page 2 of the Project Summary Sheet.

Step 4. At this point, complete the Planning Estimate by making gross estimates of:

- Total cost
- Total program system size
- Data base size and structure and storage
- Relative complexity of development requirements
- Program system complexity
- Percentage of time to allot to the various phases
- Project staffing and duration

Step 5. Make a recommendation on whether or not (1) the system is feasible, (2) it should be contracted, and (3) planning should be continued.

Step 6. Coordinate the review of the Planning Estimate and the decisions on the recommendations in Step 5 above and revise the Planning Estimate and recommendations to incorporate the results of the review. Cease or continue planning, according to the decisions made.

PLANNING TASK 2. INFORMATION COLLECTION

Collect information (from the user and other sources) about the proposed and existing system and its environment, equipment configurations, and modes of operations, and about system production requirements.

The information to be gathered in this planning task is similar to, but less detailed than, the information required for the actual system design. For an internal Project, this information represents the beginning of system analysis. For a Project to be contracted, it represents the information necessary to formulate a statement of requirements and a statement of work for a contract proposal request.

The steps to be taken are:

Step 1. Contact the user or Project requester, hardware manufacturers, and other development agencies, as necessary, and arrange for:

- Conferences and briefings
- Security clearances and access to information
- The collection and transmittal of pertinent documentation
- Visits to existing installations
- Interviews with user personnel

Enter the names of contacts on the Project Summary Sheet.

Step 2. Conduct conferences and briefings, interview users, and observe current operations. During Steps 1 and 2, look for the following problems and clues to both design requirements and improved planning estimates (see Check Sheets for System Analysis, Tasks 2 and 3):

- Existing and potential system inefficiencies
- Possible approaches and or methods of attack for design of the total system or parts of it
- Possible problem areas, such as functions that will be difficult or costly to program
- Possible interaction problems such as points of friction, e.g., users or other organizations participating in the Project that seem reluctant or unable to provide information

. Especially easy areas of development, e.g., possible use of (1) routines or programs from an existing system, (2) other systems or libraries, and (3) other design or programming techniques that may be directly applied. In these cases, try to get the specific products to actually assess the ease of transfer.

Step 3. Determine the computer to be used in producing the program system (see Check Sheet for System Analysis Task 4) and make gross estimates of:

. Turnaround times

. Priority and work loads

. Procedures and operating system

Step 4. Identify similar and interfacing systems (see Check Sheet for System Analysis Task 5) to determine possible processing requirements and constraints and to identify routines, functions, and data files that might be transferable and/or furnish a basis for costs.

PLANNING TASK 3. GROSS SYSTEM ANALYSIS

From an analysis of the information gathered, design and evaluate a preliminary model of the operational system. Determine system size and complexity more accurately and evaluate the expected equipment configuration and usage.

This analysis must be detailed enough to provide material for a contract statement of work and to permit evaluation of proposals. The work is an iteration of System Analysis Tasks 2, 3, 4 and 5. Therefore, inputs will be preliminary results of the earlier work done in these tasks. In this planning task, the Project Leader (with substantial contractor help in case a contract is let) produces a Project Development Plan.

The steps to accomplish this analysis are:

Step 1. Prepare preliminary descriptions of:

- The existing system
- The existing user organization for related information flow
- The proposed system
- The proposed user organization for related information flow
- System inputs and outputs
- Operational functions and the proposed mode of operation
- The proposed equipment configuration
- System interfaces
- Available programming tools and facilities

Step 2. Issue these descriptions for review and also as part of a Request for Proposal when contract help is sought.

Step 3. Summarize the planning information obtained on the Project Summary Sheet:

- On page 2, enter estimate the costs of performing System Analysis Tasks 6 and 7.
- In Manning Assumptions, enter estimates of experience and skills levels required to perform the various tasks, and names of key personnel who are needed for successful Project conduct.

- In Lead Time Assumptions, enter notes on key events or conditions such as elapsed time to reach assumed levels of manning or training, expected delivery dates for computers and any other key equipment, or delivery dates for compilers and operating systems.

- In Contacts, identify individuals who will represent the various agencies involved in this Project.

Step 4. Determine the computer and support program requirements and availability and enter the following under Computer Usage on the Project Summary Sheet:

- Computers to be used for program production and test and their location.

- Programming language and operating system to be used.

- Expected date of first use of the computer, the probable maximum usage of the machine, and desired turnaround time.

In the Comments column, note the following and other relevant information:

- Evaluation of the reliability of the computer and programming tools.

- Probable competition with other uses of the computer, and the priority of these Projects or activities.

Step 5. Coordinate the review and approval of the above analysis work and/or contract proposal and issue the Project Development Plan.

The Project Development Plan is a more detailed and accurate forecast than the Planning Estimate and contains an estimate of the calendar time, the effort in man months, and other quantities related to Project progress. It lists starting date, completion date, man months allocated, and progress indicators (quantity required and unit of measure) for each Phase in the Project Development Plan. Depending upon the complexity of the Project, the Project Development Plan must be prepared either 60 or 90 days after Project initiation.

PLANNING TASK 4. PRELIMINARY PROGRAM SYSTEM DESIGN

To help complete the estimate of Project costs and schedules, lay out a preliminary program system design in terms of overall functional blocks, and compare the proposed system to similar existing systems. The steps in planning during preliminary program system design are:

Step 1. Identify systems with similar features to exploit this experience, if possible, by using cost data, designs, and development methods for planning and developing the proposed system. Look for similarities in programs and routines, applications, computers and other equipment, and Projects for the same user.

Sources to consult are:

- Past and current Project files
- Libraries of professional books, journals, and reports
- Lists of SHARE, CO-OP, and other subroutine libraries
- Experienced personnel such as other Project Leaders and consultants
- Colleagues in the field

Step 2. Divide the program system into subsystems, by identifying relatively independent sets of functionally related requirements. Here, the words program systems are used in a relative sense. For example, in a large, new information system, one division may identify (a) operational programs (i.e., those programs that contribute directly to the system mission), (b) operational support programs (those programs that do not directly perform operational work, but are necessary to support the operation of the system), and (c) program production and checkout (utility) programs. (At NAVCOSSACT this type of system development would embrace a large number of Projects.) In other cases, the program system to be divided would be only one or part of one of these programs. If necessary, divide the subsystems into smaller blocks such as programs and major subroutines. It is suggested that individual Project Summary Sheets be initiated for each major subsystem and that subsequent tasks be repeated for each subsystem.

Note that the Summary Sheets, Program Planning Sheets, and Program System Planning Sheets are sufficiently flexible to be used for a range of possible program system heirarchies.

Step 3. For each subunit identified, record the identifying information on a Computer Program Planning Sheet (see work sheets at the end of the Guide), including program name, function and type of job.

Step 4. On the second page of the Summary Sheet, record estimates of the cost of performing the seven designated tasks of the System Design Phase.

PLANNING TASK 5. DETERMINATION OF WORK

To assess in detail the work to be done, examine each program and estimate the man months, computer hours, and elapsed time necessary to produce and test the programs. Identify and establish the program flows, functions, inputs and outputs, and testing requirements for each program. To be sure that tasks or important aspects of the work are not overlooked, refer to the appropriate Check Sheets in costing the various programming tasks. The costs to develop individual programs and to test subsystems are to be recorded on the Computer Program Planning Sheet and the Program System Planning Sheet, respectively. Later these are to be summed and transferred to the Project Summary Sheet. Initial entries should be tentative, subject to revision after planning of this phase is complete and prior to recording them in the Summary Sheet.

Step 1. For each program, develop a tentative, broad flow diagram of system operations (see Program Development Tasks 2 and 3) that shows:

- Inputs--messages, number of types, rates
- Outputs--messages, number of types, rates
- Data flows through the system
- Intermediate data structures
- Processing functions
- Feedback, monitoring, interrogation, and response loops
- Cyclical or temporal relations of functions and data flows

Step 2. For each program, estimate the work required to perform the following Program Design tasks (see System Design Task 2 and Program Development Task 2) and enter the values on the Computer Program Planning Sheet.

- Logic Analysis and Flow Chart
- Timing/Analysis
- Design Review
- Program Specifications

Step 3. Analyze the broad flow diagram to identify data structures and manipulation requirements and to determine functions and data structures that:

- Are similar or identical, e.g., with respect to design, I/O sources, and operating speeds
- Operate in the same time intervals
- Are highly interdependent or interactive

Step 4. Record the Data Description entries for each program on the Program Planning Sheets:

- Number of items of data to be processed
- Number of different input and output formats
- Number of data tables to be designed
- Number of constants and parameters
- Number of files
- Number of pages of documents to describe all the data

Step 5. Estimate the work necessary to perform the following Data Design tasks for each program and enter these estimates on the respective Program Planning Sheets:

- Data Analysis
- Input and Output Formats
- Data Design
- Storage Allocation
- Data Review
- Documentation

Step 6. Describe each program in terms of size, complexity, and familiarity. Some techniques to help make these estimates are:

- Comparison with similar programs or routines in previous Projects, in the literature, or in subroutine libraries.

In addition to comparison of size and complexity, special attention should be paid to differences in generality, modularity, language, operating system, and function.

- Make use of short design and coding trials by roughly flowing and actually coding sections of the programs. These trials should sample most functions but stress possible difficulties such as control and feedback loops and interfaces. Although time-consuming, this sampling of the work yields fairly accurate estimates of size, complexity, and difficulty.

- Solicit and use expert opinion and diagnosis. Although subject to possible bias, experienced persons, when dealing with systems that are similar to them, can often make relatively good estimates of size and complexity, and can also detect conditions likely to cause difficulty. However, experts in a single function may overlook program system communication, housekeeping, and I/O requirements. Be sure an estimate includes these, since, depending upon the system design, they may comprise up to 40 percent of small programs.

Step 7. Record the following information in the Program Description section of the Computer Program Planning Sheet:

- Number of instructions, divided into two estimates--one of new code and one of old or revised code--to get an idea of the proportion of innovational or unfamiliar coding involved. Reference any old programs with usable code or design in the Remarks area on the reverse side of the Program Planning Sheet.

- In the space for Number of Blocks, enter the number of functions and subfunctions involved.

- The entry for Complexity must be a local standard, such as a scale of one to five, that reflects not only the number of interactions among subfunctions and the number of interfaces with other programs, but also the number and variety of data types input, manipulated, and output; or, the standard could actually be a rough count of these items.

At NAVCOSSACT a Complexity Factor* has been defined for the total system to be developed and is presented in the Project Leader's Guide.

- Enter estimates of the number of pages of documentation for the program. If no better estimate is available, a minimum documentation estimate of one page per hundred instructions may be adopted. If the program is new or complex, and study is thus required for design and use of the program, more documentation may be required.

Step 8. After estimating the program size, estimate the cost of performing the tasks of coding, desk checking (see Program Coding Tasks 1 and 2) and keypunching, and enter the cost of the tasks required for each program on the Program Planning Sheet.

Step 9. Estimate the cost of compiling and checking the code for each program, and of designing and running individual program tests. (See Program Checkout Tasks 2 and 3.) Assume a minimum of three trials per program for test. Enter the results under Checkout Description on the Program Planning Sheet.

Step 10. Although the detailed planning for system testing will occur later, make rough estimates of the number of tests that will be run for subsystem and system testing, and the number of trials that the tests will require, and enter these estimates on the Checkout Description area of the Program System Planning Sheet.

- The number of tests for subsystem testing may be estimated by determining the number of pairs of interfacing programs, the number of triplets, and the number of other subsets of interfacing combinations, and by scheduling at least one test for each interface combination. (Other assembly procedures are possible; for example, plan tests for each required operational function and string together (often via an executive routine) those programs that contribute

* At NAVCOSSACT, the Degree of Factor Complexity as defined in NAVCOSSACT Instruction 5230.1A provides a technique for rating complexity of the development using a matrix of factors versus degree. The factors include originality required, degree of generality, span of operation (geographic dispersion), change in scope and objective (anticipated), equipment complexity (ranging from one machine to multicomputer with automatic I/O), number of personnel (including contract size), and cost.

to the function, whether they interface or not. One program may be involved in several "string" tests since it normally contributes processing to several functions. Tests may also be planned for evaluating interactions with particular items of system equipment.)

- At least two system tests should be planned, an easy one (with simple inputs) to determine that the system will operate, and one quite difficult (heavy load) to evaluate performance. As with subsystems, individual system functions should also be tested to evaluate them separately, i.e., free of the obscuring effects of interacting functions. If several versions of the system are to be produced for installation at different locations, tests should be planned for the different versions. This system test planning may also include plans for the Demonstration test.

- Despite careful programming and thorough debugging, programs seldom pass the first test. Hence, at least three trials per program system test should be planned. Early tests will probably take even more trials; later tests may take less. If the system has several versions e.g., one for each of several locations, similar trials should be planned for each unique version.

Step 11. Estimate the cost of performing the Program System Checkout tasks (see Program Checkout Tasks 4 and 5) and enter the results on the Program System Planning Sheet.

Step 12. From the Program Planning Sheets and the Program System Checkout Planning Sheets, sum the costs of Program Development, Program Coding, and Program Checkout tasks for all programs in the particular system and enter the results on the Project Summary Sheet. If separate Summary Sheets are maintained for subsystems, sum onto the subsystem Summary Sheets and then onto a master Project Summary. Entries should be regarded as tentative, subject to later revision.

Step 13. Estimate, on the basis of the results of the previous planning, the costs of the components, the planned work for user documentation, user training and assistance, and turnover phases and enter these estimates on the Project Summary Sheet. (See User Documentation, User Assistance, and Turnover Task Check Sheets.)

PLANNING TASK 6. SCHEDULE ESTIMATION

Prepare detailed schedules for the overall Project and for the tasks and components of the system. (Section IV of the Planning Guide provides additional discussions of schedule considerations.)

Step 1. Lay out rough time-line schedules to indicate the general time periods during which various tasks are to be performed. See Chart VI for an example of a Gantt Chart. For large program systems in which some subsystems may have to be developed first, e.g., utility, separate graphs should be drawn for each independent program subsystem.

Step 2. Lay out time-line schedules for:

- Each of the individual programs as recorded on the Computer Program Planning Sheets.
- Each of the subtasks of the tasks involved in the System Analysis, System Design, Documentation, User Training and Assistance, and Turnover Phases.

Step 3. Prepare a general sequence of work or network analysis schedule to depict, in graphic form, the sequences in which work must be done. Network analyses show the dependencies of one task upon the successful completion of others and indicate the shortest time (the longest or "critical path") in which the job can be done with the cost, productivity, and delay time assumptions that have been made. A way in which these dependencies are diagrammed is shown in Chart VII, an example of a network analysis for the System Analysis Phase. In prepar g a network analysis, give special attention to:

- Task dependencies.
- Critical deadlines, such as the delivery and availability dates for computers and the utility system.
- Review, concurrence, and decision points.
- Large periods of "slack time" that permit some work to be done in parallel to reduce lead times.

Step 4. Reconcile differences between the detailed schedules (Step 2) and the overall schedules (Steps 1 and 3). All of these schedule representations, Planning Sheets, Gantt Charts, and networks should be aligned so that they agree. To make this alignment, tentative plans should be adjusted by:

Chart VI. An Example of a Gantt Chart for a Programming Project

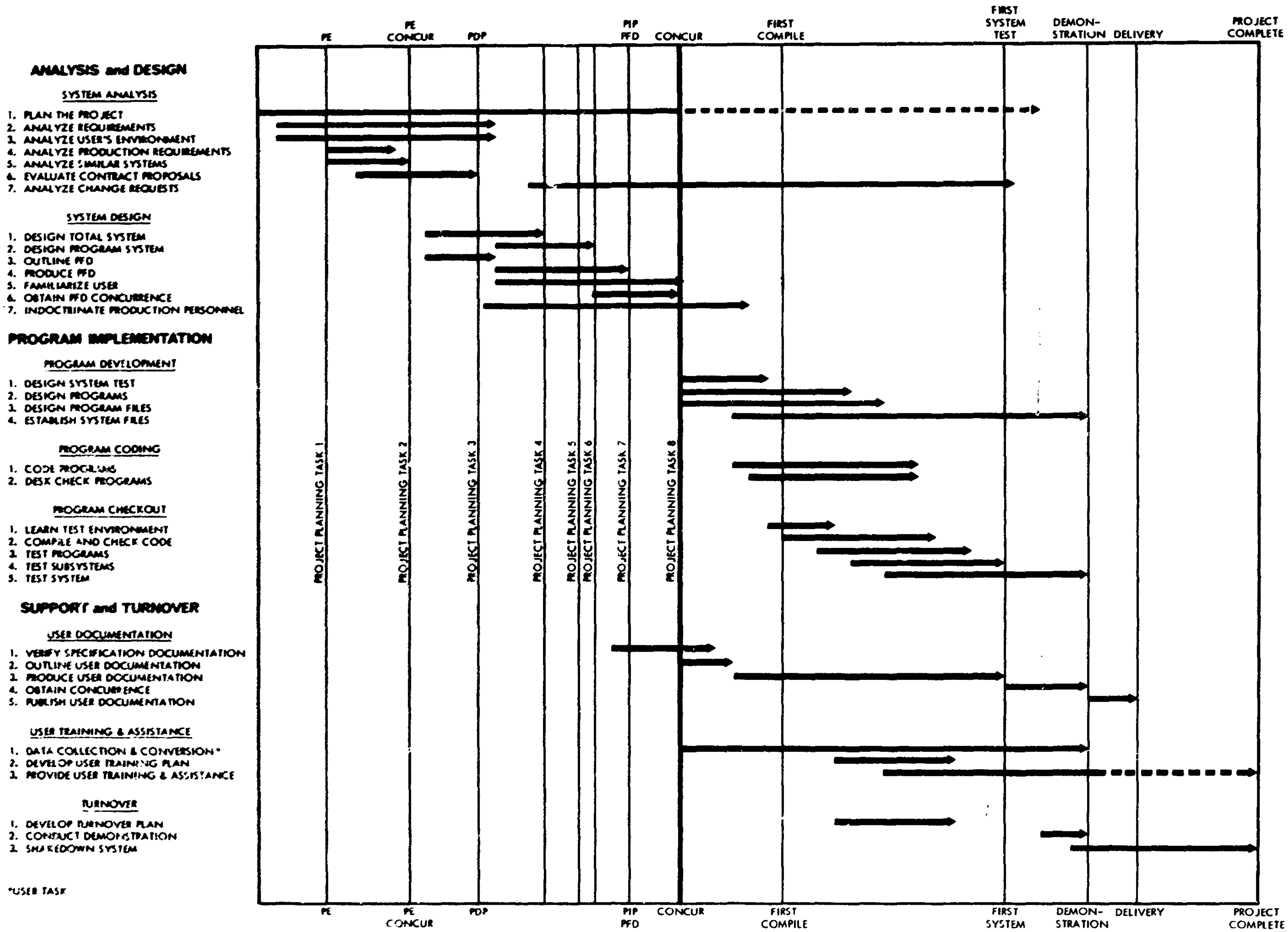
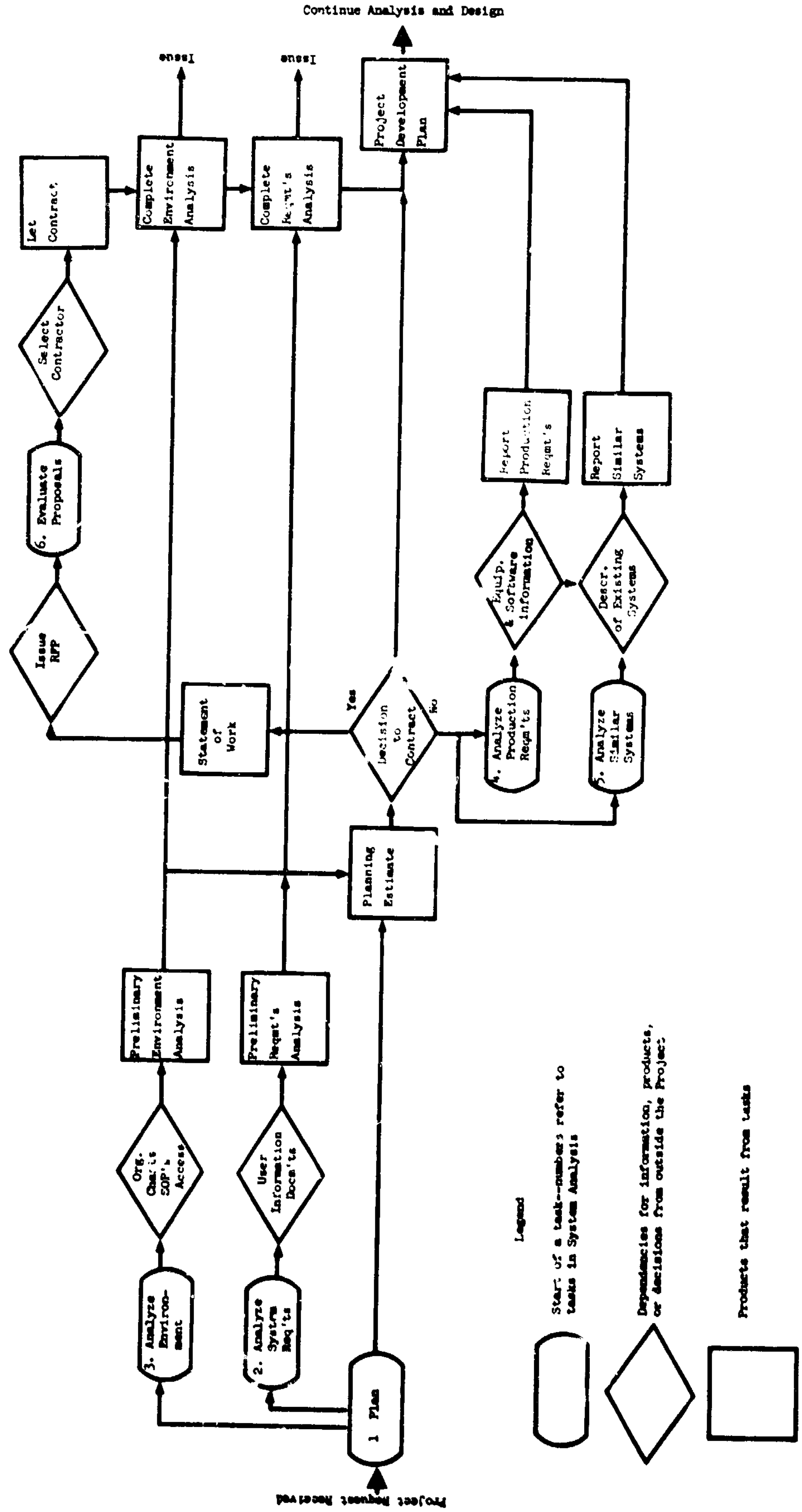


Chart VII. An Example of Network Analysis for System Analysis



- Increasing or decreasing estimates of manpower allocations.
- Reducing or removing proposed system features.
- Reducing proposed quality and performance levels.

Step 5. Enter proposed start and completion dates on Program Planning Sheets and the Project Summary Sheets. On the Summary Sheets the Coding and Checkout dates should span the entire range of time for coding and checking out individual programs as indicated on the individual Program Planning Sheets. It may be necessary to adjust earlier manpower and computer time estimates, to account for changes that result from the schedule analysis in Step 4. Record any assumed conditions that critically influence lead time in the Lead Time Assumptions section of the Summary Sheet.

Step 6. Review the assumptions that have been made for computer usage by:

- Summing up estimates of computer time by computer, language, operating system, and location.
- Realistically estimating the number of competing users of the computer and the Project priority, and then estimating the expected average amounts of computer time for the Project per day and per week.
- Estimating the average amount of computer time each programmer is expected to need.
- Estimating the expected turnaround time for Project work, considering competition and priority, plus other factors such as the accessibility of the computer location and the known or estimated efficiency of the computing facility.

Step 7. Enter these revised values, along with the forecast date of first use, in the Computer Usage section of the Project Summary Sheet.

PLANNING TASK 7. PRELIMINARY REVIEW

Integrate costs, schedules, and all plans by reviewing them with the Project members and with other Project Leaders.

The basic costing is now done; the sequence of study, information collection, analysis, design, costing, and scheduling is complete. This first detailed analysis may contain many oversights, redundancies, and contradictions. The steps taken to detect and eliminate such discrepancies are:

Step 1. Study the costs and dates recorded on the Project Summary Sheets, Computer Program Planning Sheets, and various schedules, to evaluate their reasonableness and to detect contradictions between detailed and overall schedules.

Step 2. Review the reasonableness of Project plans, particularly costs and schedules, with other Project Leaders or objective expert personnel.

Step 3. Lock for and identify omissions and redundant efforts.

Step 4. Correct oversights, remove redundancies, and adjust contradictions.

PLANNING TASK 8. OBTAIN CONCURRENCE

Document the plans for the implementation of the program system and obtain the concurrence of higher management and the customer. The coordination and concurrence for the Project Implementation Plan and Preliminary Functional Description (see System Design Task 6) should be concurrent.

The steps taken are:

Step 1. Draft the Project implementation plans. Emphasize statements of mission and objectives, descriptions of activities and products, and discussions of assumptions and limitations that will make graphic and numeric information meaningful to the reader who is inexperienced with ADP. Recommendations may be made concerning the continuance, priority, and feasibility of the Project.

Step 2. Submit plans and recommendations to management for coordination, review, and approval.

Step 3. Cooperate with management in their evaluation of the plans by:

- Presenting briefings.
- Attending conferences.
- Providing additional information.
- Clarifying assumptions, specifications, and estimations.
- Trying to answer objections and responding to suggestions raised during the evaluation.

Step 4. Revise plans until management concurrence and approval is received.

Step 5. Prepare drafts of the plans for coordination with the user.

Step 6. Cooperate with the user and his agents in their evaluation of the plans as in Step 3.

Step 7. Revise plans until customer concurrence is achieved.

Step 8. Publish the Project Implementation Plan.

IV. GUIDELINES FOR ESTIMATION

In the development of a specific program or program system, the cost of any task or subtask depends on numerous factors, such as the size and complexity of the program being developed, the resources including the personnel, methods and tools used for development, and the particular conditions under which the programs are produced. This section describes some cost factors that the Project Leader should consider; presents some guidelines that may be used for cost estimation and scheduling; and displays some equations and raw data that are the results of research in cost estimation.

As one might expect, larger Projects incur larger costs. Experience shows that increases in size, complexity, and integration of computer programs into a system lead to a need for increased division of labor and coordination as follows:

- To meet reasonable development schedules, work must be divided into tasks that can be handled by a single person.
- Tasks that may be subsumed in a small effort now become large enough and important enough to have one or more persons assigned to them full time.
- The time and effort needed for (and usually spent on) system analysis, design, and testing increase much faster than the time spent on detailed programming and coding.
- The interdependencies of programs increase rapidly so that the need for coordination and communication among the programs and in the corresponding development work grows exponentially.
- Correspondingly, the need for management, supervision, and control increases greatly.

Although the guidance given below reflects some of these, the Project Leader should keep these characteristics in mind to aid his judgment.

A. COST FACTORS IN PROGRAM DEVELOPMENT

The many factors that influence Project difficulty or cost may be divided into three groups:

- The nature of the job to be done--the nature, clarity, and extent of system requirements.
- The wherewithal--the amount and availability of the various resources (personnel, machines, and information) required to do the job.

- The environment--the conditions under which the Project is managed and the program must be developed.

Developed from a survey of experience in program development, Chart VIII is a matrix showing a summary of cost factors as they are qualitatively related to the tasks. The Check Sheets include a more detailed list of cost factors. The 36 tasks describing the system development process are listed on the left side of the matrix, the factors above. Factors are grouped into the three categories: Requirements, Resources, and Development Environment. A plus sign appearing at the intersection of one of the factors and one of the tasks means that the presence of that factor will increase the cost of the task; a minus sign indicates that its presence will decrease the cost of that task. The extent to which the factor is present determines the degree to which it increases or decreases the task cost; e.g., the greater the amount of programmer experience, the greater will be the extent to which the cost of the programming task is decreased. On the other hand, some factor/task relationships do not exist in degrees; e.g., if the computer used for development is not the same one as the computer used in actual operation, project planning and development costs will be higher. (If data were available, this chart could be used to make detailed comparisons of factors in a new Project with factors in completed Projects.)

B. GUIDELINES FOR ESTIMATION

Although the prediction of programming costs is still largely uncertain and inaccurate, better costing formulas are gradually evolving. However, as long as programming includes a large amount of development work and information generation, some inaccuracy of prediction must be expected. The accuracy of prediction depends upon the accuracy of assessment of the many factors that influence the work. Also, until the influence of these factors can be established conclusively, the initial estimation of costs must rely upon experience and rough rules of thumb. But in any specific Project, as work proceeds, the influence of specific factors will become clearer and, hopefully, quantitative. Therefore, planning, including the estimation of costs and schedules, is viewed as an ongoing function of the Project Leader, and estimates will change several times during the course of a Project. Generally, each revision of the plan is more accurate than the preceding one.

In planning, the Project Leader must make estimates of the costs of the programs in terms of:

- Manpower

- Computer Time

- Elapsed Time

Chart VIII. Cost Factor-Task Matrix

TASKS / FACTORS	REQUIREMENTS 1. INNOVATION IN OPERATIONAL SYSTEM	2. USER PARTICIP. IN REQ'TS ANALYSIS	3. SYSTEM CHANGES	4. SYSTEM COMPLEXITY	5. CONCURRENT SYSTEM DEVELOPMENT	6. SYSTEM DISPERSION	7. SIZE OF PROGRAM SYSTEM	8. NUMBER OF INPUTS & OUTPUTS	9. INNOVATION IN PROGRAM SYSTEM	10. PROGRAM SYSTEM COMPLEXITY	11. DESIGN CONSTRAINTS	12. PROGRAM CHANGES	13. SIZE OF DATA BASE	14. ADEQUACY OF TEST REQUIREM'TS	15. NUMBER OF DISPLAYS	RESOURCES 1. AMT. DOCUMENTATION AVAILABLE FOR UTILITY PROGRAMS & ADP EQUIPMENT	2. AVAILABILITY OF PROG'G. TOOLS	3. AVAILABILITY OF COMPUTER TIME	4. PROGRAMMER EXPERIENCE	5. PERSONNEL TURNOVER	DEVELOPMENT ENVIRONMENT 1. DOCUMENTED MANAG'T PLANS FOR: a. SYSTEM DESIGN CHANGES	b. PROGRAM DESIGN CHANGES	c. ERROR CORRECTIONS	d. COMPUTER USAGE	e. STANDARDS; CODING, FLOW CHARTS	2. NUMBER OF CONCURRING AGENCIES	3. USER EXPERIENCE	4. CONCURRENT EQUIPMENT DEVELOPMENT	5. PROGRAM DEVELOPED MORE THAN ONE LOC'N.	6. COMPUTER FOR DEVEL. DIFF. THAN OPER'NS.
SYSTEM ANALYSIS																														
1. PLAN PROJECT	+	-		+	+	+	+	+	+							-				+				-		+	-	+	+	
2. ANALYZE SYSTEM REQUIREMENTS	+	-	+	+		+		+							+											+	-		+	
3. ANALYZE USER'S ENVIRONMENT		-				+																					-			+
4. ANALYZE PRODUCTION REQ'TS.			+		+		+				+	+	+	-		-	-			+									+	
5. ANALYZE SIMILAR SYSTEMS	+			+					+	+																				
6. EVALUATE CONTRACT PROPOSALS	+			+			+		+	+																+				
7. ANALYZE CHANGE REQUESTS			+	+	+	+	+																			+				
SYSTEM DESIGN																														
1. DESIGN TOTAL SYSTEM	+	-	+	+	+	+		+			+		+		+												-			
2. DESIGN PROGRAM SYSTEM			+				+	+	+	+	+	+	+		+				-											
3. OUTLINE PFD		-		+		+	+																							
4. PRODUCE PFD	+	-	+	+		+	+																							
5. FAMILIARIZE USER	+	-		+		+	+	+	+	+			+		+												-			
6. OBTAIN PFD CONCURRENCE		-	+	+																						+	-			
7. INDOCT. PRODUCT'N PERS.	+			+			+	+	+	+	+	+	+	-		-	+		-	+	-	-	-	-	-					
PROGRAM DEVELOPMENT																														
1. DESIGN PROGRAM SYST. TEST	+	-	+	+	+	+	+	+	+	+		+	+	-	+	-			-		-	-				+	-		+	
2. DESIGN PROGRAMS							+	+	+	+	+	+	+		+	-			-			-			-					
3. DESIGN PROGRAM FILES								+	+	v	+	+	+		+				-											
4. ESTABLISH SYSTEM FILES		-		+	+	+		+					+				-		-											
PROGRAM CODING																														
1. CODE PROGRAMS							+				+	+				-			-			-	-		-					
2. DESK CHECK							+	+	+	+		+							-	+					-					
PROGRAM CHECKOUT																														
1. LEARN TEST ENVIRONMENT													+	-	+	-	-		-					-				+	+	+
2. COMPILE & CHECK CODE																-	-	-	-					-	-					
3. TEST PROGRAMS							+	+	+	+		+		-		-	-	-	-	+		-	-		-					
4. TEST SUBSYSTEMS							+	+	+	+		+		-	+	-	-	-	-	+		-	-		-			+		
5. TEST SYSTEM	+	-	+	+	+	+	+	+	+	+		+		-	+	-	-	-	-	+	-		-		-	+	-	+	+	+
USER DOCUMENTATION																														
1. VERIFY SPEC'N. DOCUMENT'N.	+		+	+	+		+	+		+		+	+		+						-	-					-			
2. OUTLINE USER DOCUMENT'N.				+		+																				+	-			
3. PRODUCE USER DOCUMENT'N.				+		+	+	+	+	+		+	+		+	-														
4. OBTAIN CONCURRENCE		-	+																							+	-			
5. PUBLISH USER DOCUMENTATION			+									+																		
USER TRAINING & ASSISTANCE																														
1. DATA COLLECT. & CONVERSION													+														-			
2. DEVELOP USER TRAINING PLAN				+						+					+												-			
3. PROVIDE USER TRAINING & ASSIST.	+	-		+			+	+	+	+			+			-											-			
TURNOVER																														
1. DEVELOP TURNOVER PLAN	+			+	+		+	+	+	+			+			-											+			
2. CONDUCT DEMONSTRATION		-		+				+							+												+			
3. OPERATIONAL SHAKEDOWN	+	-	+	+	+	+			+	+			+		+													+		+

1. Computer Time Estimates

On most Projects, gross estimates of computer usage are adequate. That is, estimates of the computer time needed to check out any one program are usually quite inaccurate, but rules of thumb appear to come surprisingly close to actual expenditures. Two basic methods are:

a. Estimate computer hours as a function of the number of programmers and weeks of computer usage. Depending upon the conditions of use and the number of programmers competing for time, computer usage averages between eight and fifteen minutes per man day, or between two-and-a-half and four hours per man month. That is, 30 to 60 programmers can use one to two shifts of computer time per day in compilations, code checks, data generations, and program tests.

b. Estimate computer hours as a function of number of instructions. Great variation exists in the amount of time taken to check out any one routine or program. However, a rough rule of thumb for moderately large systems is one checked-out instruction per minute of computer time. For small and simple programs, for program rewrites, and for program conversions from one computer to another, less time will be required. For large systems with many interfaces and tightly integrated functions, more will be required.

For initial estimates, these rules are usually adequate. Because of unforeseen difficulties in computer usage and availability it is good practice to reforecast computer time requirements frequently.

2. Programmer Productivity

Estimating programmer production is more difficult than estimating computer time. For a programming process divided roughly into three parts, Analysis, Coding, and Checkout, the percentage of total effort devoted to these parts is shown in Table I.

From these data it may be estimated that the average allocation of effort is as follows: Analysis and Design will consume 40 percent of the manpower; Coding, 15 percent; and Checkout and Test, 45 percent. Roughly, the Analysis and Design work represented by these figures includes equivalent tasks; the same is true of the Checkout work. At NAVCOSSACT, the Coding Phase is a larger part of the work (includes more tasks) than that implied by the other entries under Coding in the Table. For example, at NAVCOSSACT, design of individual programs and their associated documentation would be included in Coding, but in the other programming efforts this work was included in Analysis and Design. Despite these differences, the average values agree with NAVCOSSACT experience.

TABLE I. RELATIVE COSTS OF PROGRAMMING PROJECT PHASES*

	SETE** (%)	SAGE*** (%)	NTDS**** (%)	NAVCOSSACT (%)	AVERAGE (%)
Analysis and Design	35	39	30	34	34.5
Program Coding and Checking	17	14	20	20	18
Checkout and Test	48	47	50	46	47.5

*The data on SAGE (Semi-Automatic Ground Environment) refer only to early models and not to model changes that logically might reflect costs in different proportions than are characteristic of new systems. The Project SETE (Secretariat for Electronic Test Equipment, New York University) values are averages derived from data on twelve systems produced in support of automatic test equipment for missile and other projects. The NTDS data do not include information on preliminary design and operational system analyses.

**A Survey of Programming Aspects of "Computer-Controlled" Automatic Test Equipment, Volumes 1 and 2, SETE 210/78, New York University, New York, June, 1964.

***J. P. Haverty, Programming Language Selection for Command and Control Application, Symposium Address, Symposium on Computer Programming for Military Systems, The Hague, The Netherlands, September, 1964.

****G. G. Chapin and P. A. Hensel, Programming for the Naval Tactical Data System, Symposium Address, Symposium on Computer Programming for Military Systems, The Hague, The Netherlands, September, 1964.

The analysis and design work for information processing systems involves many tasks and is frequently underestimated, undercosted, and inadequately performed. Because the later work in the process is more susceptible to measurement and can be estimated more easily, the analysis and design work may be estimated as a percentage of the coding and checkout costs using data such as those in the Table.

Coding and checkout productivity are usually estimated at 250 to 300 machine instructions per man month estimated from the start of coding to the completion of the Project (i.e., approximately 60 percent of costs). Utility and support programming fall at the upper end of this productivity range, and complex, tightly integrated systems at the lower end.

Conversion and reprogramming Projects should enjoy a much higher productivity rate, if there is adequate documentation and there are no major changes. If no major redesign of the program or system is necessary, savings are possible because most of the analytic work is eliminated. Although coding is reduced somewhat, checkout and turnover will run about the same as an original development. Savings will also be realized if the same test designs and test data can be used for the converted programs as were used originally.

Program modification, notably of large systems, is frequently undercosted. Coding a small change is usually trivial--a few minutes' work--but thoroughly investigating the impact of the change on many interrelated programs and operations may take days. Also, updating the coding is often less costly than updating the documentation of the program. As changes become larger, the proportionate costs of coding and checkout gradually rise toward the relative costs that hold for original programming. The cost of testing small changes to a large system, to be sure that the change has been made correctly and has not adversely affected any other item, is sometimes very large in comparison to the other costs of change.

3. <u>Elapsed Time</u>

In estimating the amount of time that a Project will take, people are often quite good at estimating the time for their own jobs, but are very poor at estimating how long others will take. This is particularly true when estimates are made of time to be used by non-Project members. For example, the times needed by higher level managers or the user to review documents are usually underestimated. Some typical examples of work that must be done by non-Project members are:

- Product inspections and reviews (e.g., reviews of documents).
- Editorial and technical reviews of documents prior to publication.

- Decisions or choices between alternative modes of procedure.
- Decisions about or approval of a product or procedure (e.g., concurrence on a document).
- Coordination and concurrence procedures.
- Evaluation of proposals (e.g., processing a change proposal).
- Establishing contact and making arrangements to meet and discuss.

At NAVCOSSACT, estimates based on experience show a minimum of 14 weeks elapsed time for processing such as obtaining documentation concurrence, security clearances for people and information, and approval for a particular design. Most of these periods may be predicted, once experience data for average turnaround time are obtained. Although the accuracy of an estimate for individual reviews may be poor, the collection of such estimates will usually contain some over- and underestimates that will cancel one another. Since the number of lengthy reviews is usually greater than the number of unexpectedly quick responses, overestimating the individual periods will pay off in a more accurate total Project schedule.

Some typical times for various non-Project activities estimated by NAVCOSSACT personnel are shown in Table II. Chart IX shows the breakdown of elapsed times for letting contracts with some comparison of these for sole source and solicited bid contracts. Project members tend to view these periods as delays. This is not true, of course, but even so, any periods of time that involve transit and wait may be shortened.

C. RESEARCH IN ESTIMATION OF PROGRAMMING COSTS

Under an Air Force Electronic Systems Division contract, SDC recently completed the first part of an exploratory study of computer programming cost factors.* Aimed at developing cost estimating equations or relationships, the analysis included use of various statistical techniques such as correlation analysis, multivariate regression analysis, and factor analysis.

*TM-1447/001/00, Factors that Affect the Cost of Computer Programming: A Quantitative Analysis, L. Farr and H. J. Zagorski, 31 August 1964.

Product	Review or Activity	Range
Project Request	Rating of Project, e.g., preliminary user contact	1-2 weeks
Planning Estimate	Establish contact with user	1-2 weeks
Planning Estimate	Approve draft in-house and non-in-house organizations	3-12 weeks
Project Development Plans	Approve in-house document	2-4 weeks
Manning	Acquire and assign personnel	4-8 weeks
Security Clearance	Clear new people	6-12 weeks
Security Clearance	Establish right-to-know and need-to-know to obtain information from user and others in researching this and other related systems	1-6 weeks
Contract-Letting Process	See Chart IX	
Preliminary Functional Description	Obtain document draft including typing and duplication	1-4 weeks
Preliminary Functional Description	Approve in-house document	3-7 weeks
Preliminary Functional Description	Approve document by users	6-14 weeks

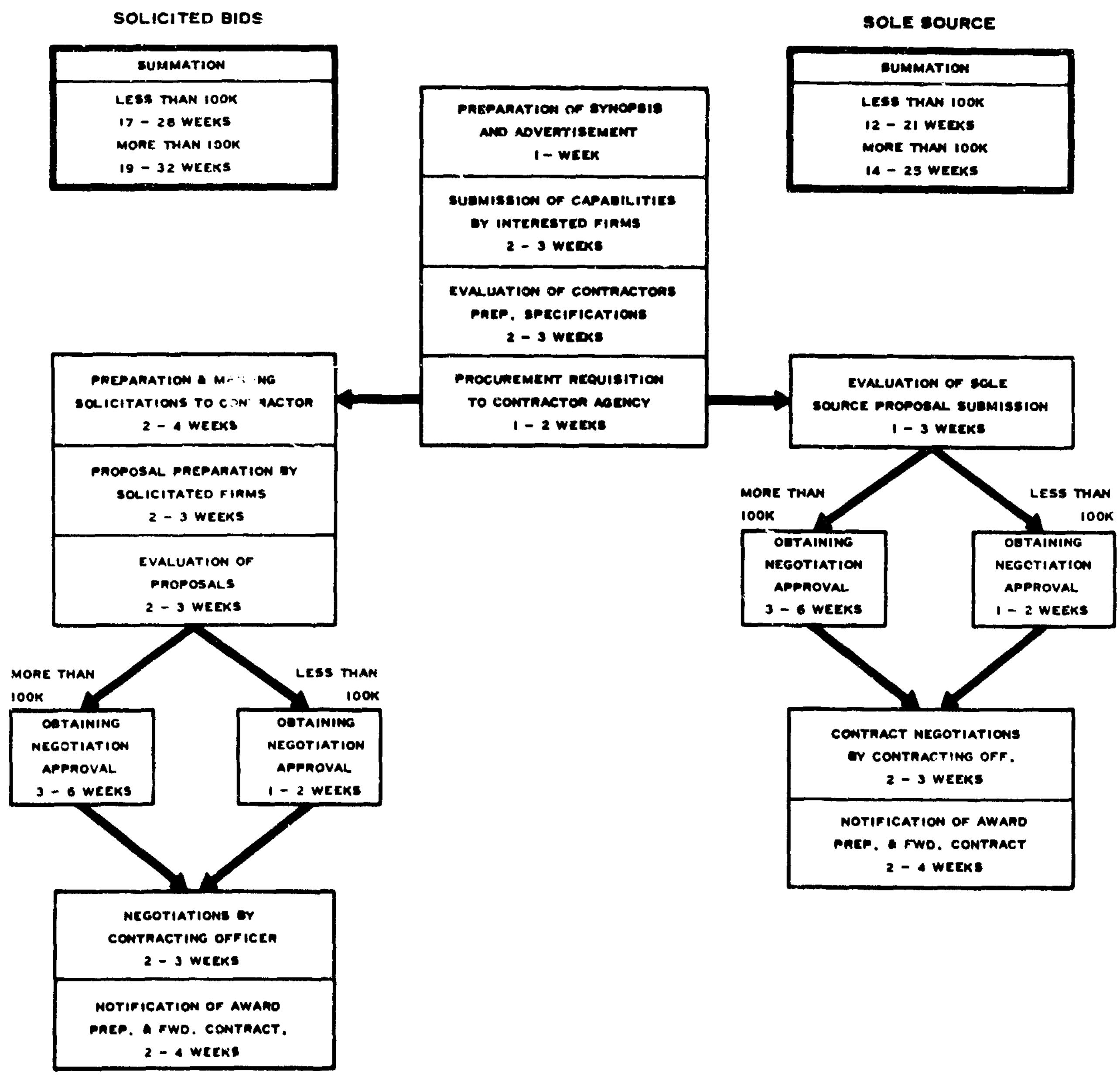
Above Activities apply to both Feasibility Studies and Programming Projects. Those below apply only to Programming Projects.

Computer Time	Maintain equipment and facility	@ 3 weeks/year
Change Request	Process change request (average: 5 changes per project)	1 week
Project Manual	Obtain draft document including typing and duplication	1-4 weeks
Project Manual	Approve in-house document	2-8 weeks
Turnover Plan	Obtain draft document including typing and duplication	2-3 days
Turnover Plan	Approve document in-house and by non-NAVCOSSACT organizations	2-8 weeks
Statement of Project Completion	Obtain final acceptance	2-12 weeks

NOTE: Many of these activities are or can be pursued concurrently with other tasks. Therefore, the times indicated do not add linearly in any schedule but help a Project Leader to schedule dependent events such as beginning a new task.

Table II. Time Estimates and Other Activities at NAVCOSSACT

Chart IX. Contract-Letting Processes and Delays



Although the statistical techniques yield meaningful estimating relationships, the equations that emerged from the first phase have large confidence limits. That is, the statistical confidence with which one can use these equations is quite low. Work is proceeding to improve the equations; therefore, they are presented here, not as tested, well-proven tools, but simply as experimental aids to be used in conjunction with judgment and experience.

Data on over a dozen cost variables and almost a hundred predictor variables were collected on twenty-seven programs and subjected to statistical analysis. Below is a summary of four of the resulting equations and some cost data for man months and computer hours presented graphically. Figures I and II plot man months and computer hours against program size in terms of the number of delivered instructions. Figure III plots computer hours against months and reveals a fairly high correlation between these two cost variables. The variable, man months, represents the cost of designing, coding, testing, and documenting the program. The scope of work is about the same as that included in the following NAVCOSSACT Phases:

- System Design (Program System Design Task only)
- Program Development
- Program Coding
- Program Checkout
- User Documentation

1. Man Months for Design, Code and Test

$$Y_1 = 2.8X_2 + 1.3X_3 + 33X_4 - 17X_5 + 10X_6 + X_7 - 188$$

Standard error of estimate* = 70 man months

Range of costs in sample = 20-900 man months

*The standard error of estimate is a measure of expected deviation of estimated data from actual data. Two thirds of actual costs should fall within one standard error of their predicted values. Since this measure tends to be constant throughout the cost estimation range, the relative percent of error to total cost will decrease as one proceeds from small programs to large programs. Thus, the larger programs are able to tolerate the estimating error much more readily than smaller programs.

<u>Variables</u>

1 Number of man months for program design, code, and test

2 Number of machine language instructions in delivered program (in thousands)

3 Number of man miles for travel (in thousands)

4 Number of document types delivered to the customer

5 System programmer* experience index

6 Number of display consoles

7 Percent instructions new to this program (not reused from previous versions)

2. <u>Months Elapsed Time</u>

$Y_1 = 2.5X_2 - .14X_3 + .11X_4 + .3X_5 + 7.0$

Standard error of estimate	= 4.8 months
Range of elapsed times in sample	= 5-56 months

<u>Variables</u>

1 Number of months of elapsed time for program design, code and test

2 Number of words in tables and constants

3 Number of words in core storage

4 Percentage of decision-making instructions

5 Number of document types delivered to the customer

*System programmer. As the most senior of four classes, he contributes to the formulation, planning, design, and development of computer program systems; experience index for the system programmer is the sum of the average number of years of experience with the specific computer-type, application, and language.

3. Computer Hours

$$Y_1 = 21.5X_2 + 985X_3 + 197X_4 - 3468$$

Standard error of estimate = 905 hours

Range of hours in sample = 130-9000 hours

Variables

1 Number of computer hours

2 Number of machine language instructions in original estimate

3 Complexity rating (scale 1 to 5--subjective from simple to highly complex)

4 Number of words in data base

4. Delivered Machine Language Instructions

$$Y_1 = 2.6X_2 + 1.2X_3 + 5.6X_4 - 13.9$$

Standard error of estimate = 25.7 instructions (thousands)

Range of program sizes in sample = 8-300 instructions (thousands)

Variables

1 Number of machine language instructions in delivered program (in thousands)

2 Number of input messages

3 Number of subprograms

4 Number of words in tables and constants

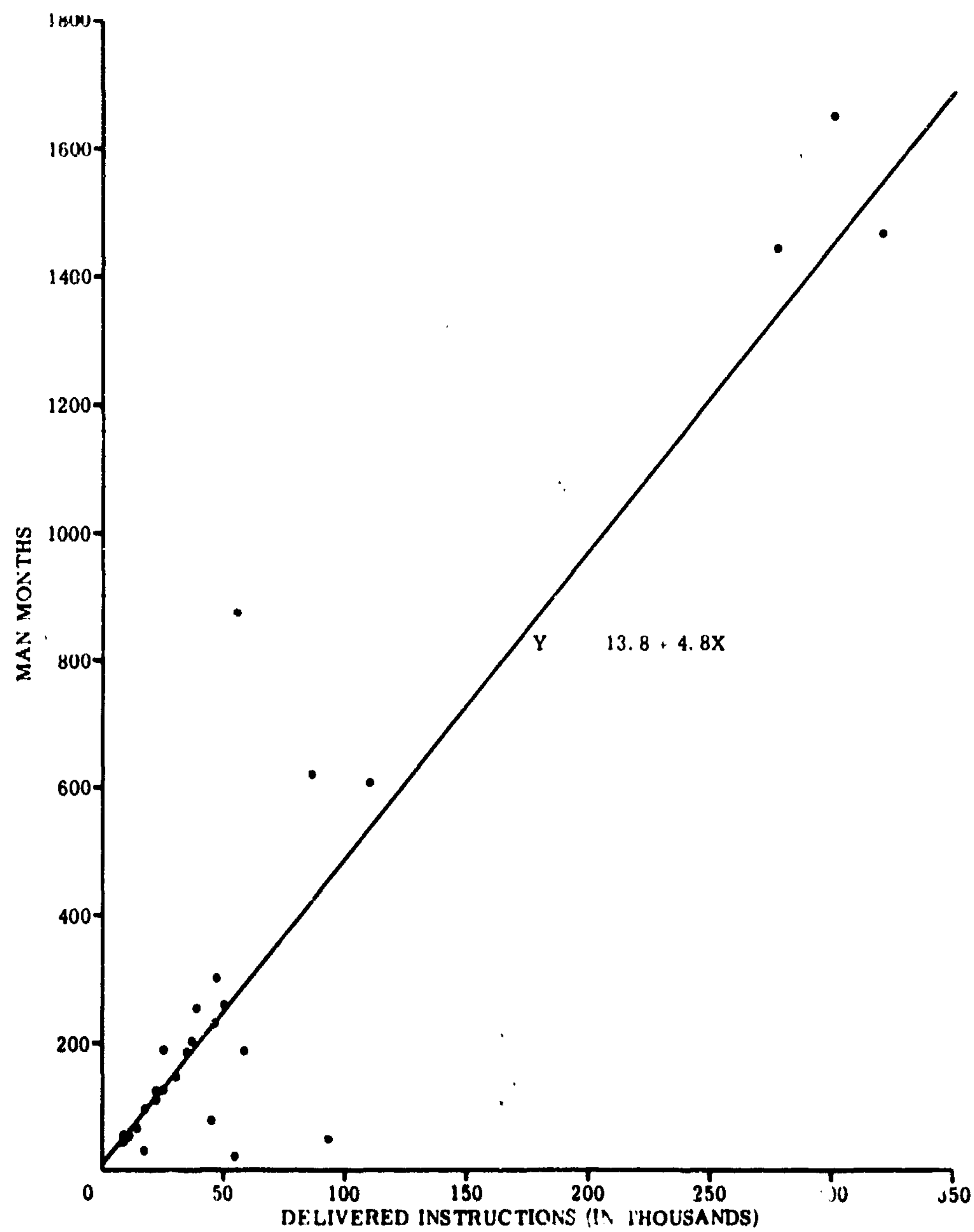


Figure 1. Number of Man Months versus Number of Instructions

(The equation represents a simple linear regression with the available data and <u>is not a reliable predictor</u>.)

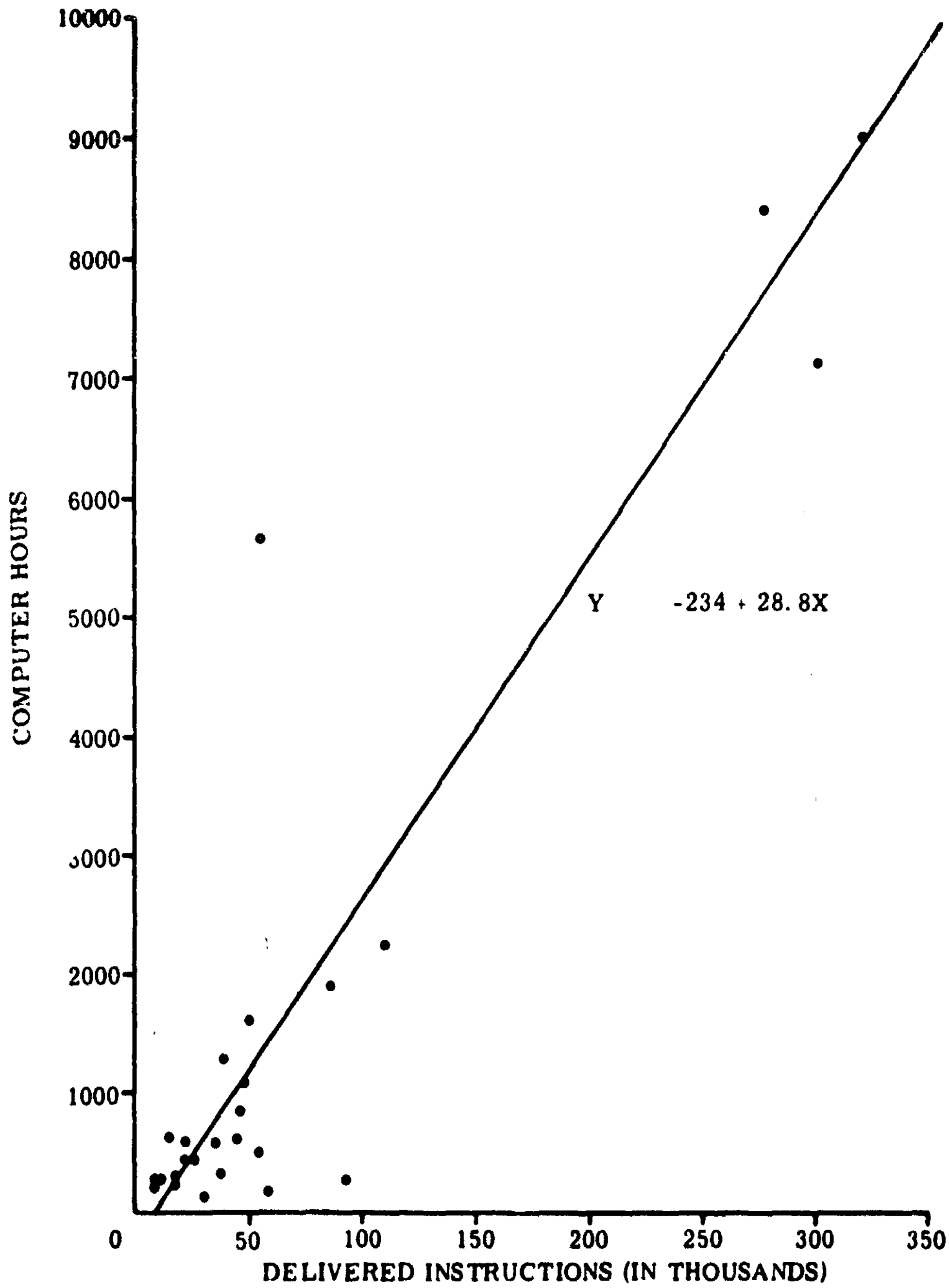


Figure 2. Number of Computer Hours versus Number of Machine Language Instructions

(The equation represents a simple linear regression with the available data and <u>is not a reliable predictor</u>.)

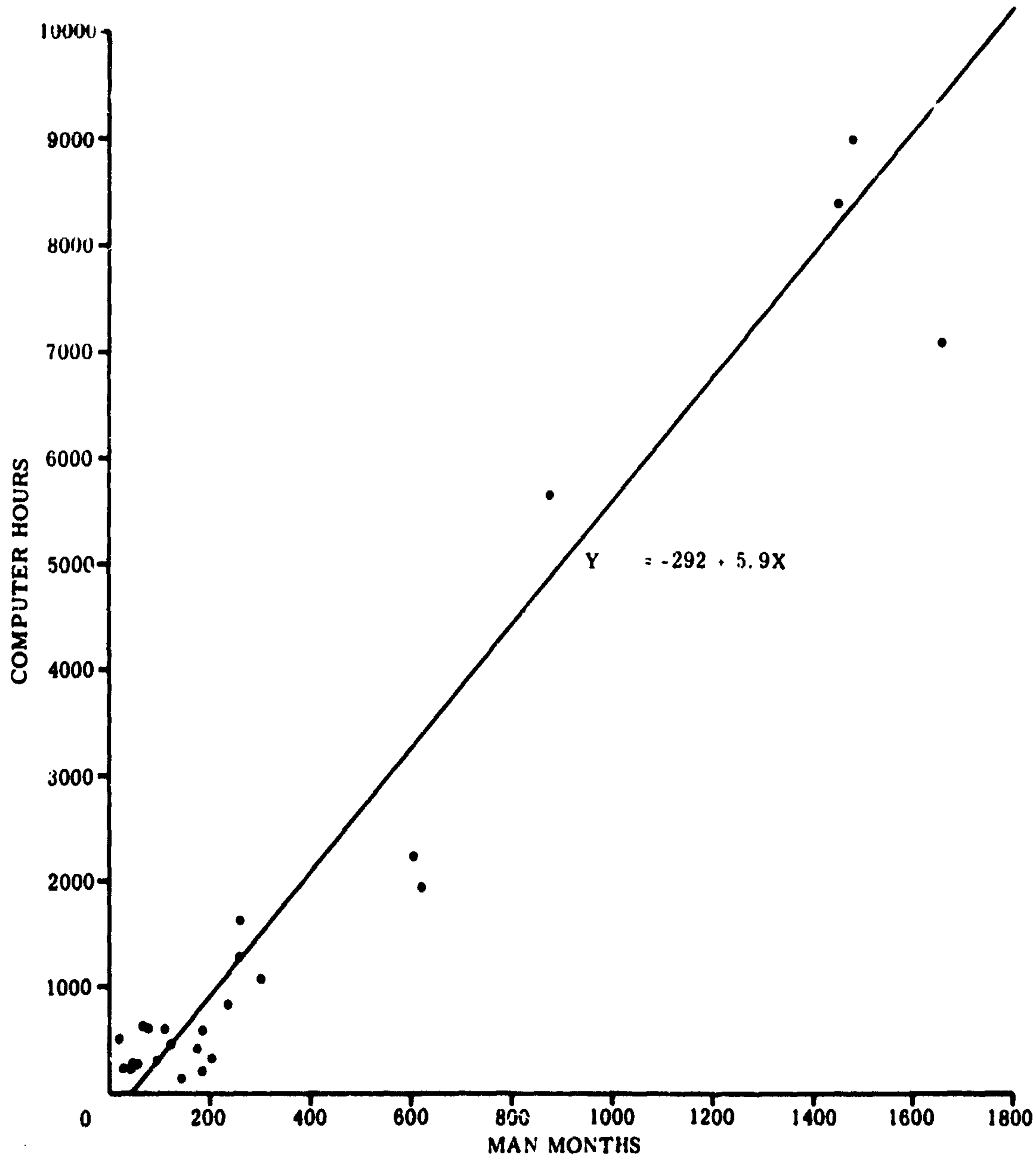


Figure 3. Computer Hours versus Man Months

(The equation represents a simple linear regression with the available data and <u>is not a reliable predictor</u>.)

V. SYSTEM ANALYSIS AND DESIGN

The process of determining the requirements for the program system and planning a set of programs capable of fulfilling them is divided into two Phases--System Analysis and System Design. The first Phase consists of investigating the particular information processing task that is to be adapted to automatic data processing methods; the second consists of attempts to devise a satisfactory solution to the data processing requirements involved.

System analysis and design is a complex process and, for a large system, can be broken down into many fine tasks and phases; in the case of a small or simple information processing task, it may be considered only a single step in the production of the program. The tasks of analysis and design that are largely intangible such as "study," "investigate," and "coordinate" may be made more tangible by requiring specific documents to record the thoughts and actions of the system analysts and designers.

A. OBJECTIVES

Generally, the mission of the analyzing and synthesizing process is to devise the most effective and efficient organization of program functions and elements possible within the constraints of available manpower, funds, and time, to perform the required data processing functions. In the case of feasibility studies, the goals of the work are more limited and involve accurate definition of the information problem and assessment of the possibility of solving it with ADP.

In the System Analysis and Design Phases, system analysts and senior programmers:

- Define in detail the information processing problem indicated in the Project Request.
- Devise one or more ways to perform the required functions.
- Evaluate these alternate designs to select the most effective and efficient solution.
- Detail the design of the program system specified by this solution.

B. TASKS

For System Analysis, the tasks are:

1. Plan the Project
2. Analyze system requirements
3. Analyze the user's environment
4. Analyze computer program production requirements
5. Analyze similar and interfacing systems
6. Evaluate contract proposals
7. Analyze requests for system change

For System Design, the tasks are:

1. Design the total system
2. Design the computer program system
3. Outline the Preliminary Functional Description
4. Produce the Preliminary Functional Description
5. Familiarize the user with the system design
6. Obtain concurrence on the Preliminary Functional Description
7. Indoctrinate production personnel

Although these tasks apply generally to all Projects, their intensity, i.e., the amount and/or quality of work needed, may vary among Projects. For example, to transfer an ADP capability that exists on one machine to another machine requires little analysis because the Project already has a "proven" program system design. Also, the Project can benefit from the earlier documentation (e.g., Project Estimate, Project Development Plan, and Preliminary Functional Description), the experience of personnel, the records of problems and their solutions, and the actual costs and schedules of the original Project. However, conversions and revisions of old programs invariably include some new analysis and programming. It is dangerous, then, for Project personnel to neglect these functions by assuming that adequate analysis and documentation has been done. Attempts to use poorly maintained documents, or subtle differences between an old and new system, sometimes lead to more costly design work than designing a new system. Therefore, the Project Leader, even in this case, must consider, in planning, all of the analysis and design tasks, and should expect to perform all of them in at least a rudimentary way.

Further, although in a small project analysis and design may be combined into a single task and done by one person, the Project Leader should recognize that the tasks are distinct in terms of time and effort. Some benefits accrue from combination but may be negated by failure to recognize individual task responsibility.

C. COMMUNICATION, COORDINATION, AND CONTROL

The analyst collects information from:

- The Project Request.
- Descriptions of the proposed and existing systems.
- Descriptions of proposed hardware.
- Descriptions of available program production tools.
- Documents stating the mission and requirements of the system.
- Conferences and briefings.
- Interviews with user and other personnel.
- Feasibility study reports.
- Descriptions of interfacing systems.
- Documents describing the user's mission, responsibilities, and organization.
- Observations of the existing systems.
- Files of previous projects.
- Interviews with expert consultants and other Project Leaders.
- Simulation studies.
- Technical literature and professional meetings.
- Analytic and feasibility studies of his own.
- Progress reports, trip reports, minutes of meetings, and similar administrative documents.
- Correspondence files.

The analyst communicates and provides coordination through:

- Personal contact with users, programmers, Project Leaders of other projects, and other developers.
- Conferences and briefings.
- Circulation of documents for review.

- Concurrence meetings
- Dissemination of trip reports, minutes of meetings, reports of studies, and confirmatory (feedback) letters and reports following contacts and interviews.
- Progress reports and other documentation.

Control is established by:

- Schedules and budgets
- Project monitoring and program reporting
- Concurrence procedures
- Design change procedures
- Documentation procedures
- Coordination procedures
- Product lists and product status reports
- Planning documents
- Review procedures
- Procedures for the verification of information

The analysis and design phases require communication because the personnel collect and generate information, and coordinate information among the programmer personnel, customer, and other developmental agencies. Most analysis work is recorded in documents whose contents must be coordinated and concurred with the customer and, sometimes, with other developers.

The analysis phase needs control mechanisms to (1) assure completeness and accuracy of information, (2) ensure complete coordination, (3) obtain decisions and concurrence, and (4) control change proposals, including their evaluation and implementation.

D. SUPERVISION

During the System Analysis and System Design Phases, this intense need for communication and coordination dictates the Project Leader's responsibilities. He and his subordinate supervisors must monitor the tasks, evaluate their products, coordinate activities, and resolve technical and administrative difficulties.

The Project Leader must make all important technical decisions. In a small Project, he himself must do the planning, set schedules and deadlines, keep abreast of progress, and evaluate all of the analyses and designs produced. On a larger Project, although he may delegate much of the planning and product review to other senior team members, he remains responsible for the final review and the technical quality of the final products.

One of the most important and time-consuming tasks of the Project Leader is the external coordination of analysis and design plans. He represents the Project in contacts with user personnel, such as briefings, information gathering, and user review and concurrence on Project plans and designs. He also represents the Project to his management by presenting briefings, coordinating plans, and obtaining design approval. The Project Leader must deal with the computer and duplication facilities and other service organizations to arrange for computer time, duplicating and illustrating services, EAM work, and other support. Project success also depends upon other coordination activities, e.g., arranging for conferences and trips, getting reviews of plans and designs, and in obtaining decisions and concurrence.

Administrative matters may be a time-consuming chore for the Project Leader, but good secretarial support can ease this burden. The Project Leader (or, on a large Project, a delegate) must review, approve, and expedite requests for trips, conferences, clearances, and information to be sure these are necessary and accomplished quickly and effectively. The Project Leader is also responsible for work assignments, time reports, progress reports, performance evaluations, salary reviews, and other administrative details.

Responsible for the efficient operation of his team, the Project Leader not only makes plans, but sees that the work indicated is done on schedule. Two particularly difficult tasks are (1) to see that the analysis and design documents are completed on schedule and are accurate and complete and (2) to handle changes to design and the plan and to document the resulting changes in a timely way.

E. COST FACTORS

For small projects, the Project Leader will need only a few skilled analysts to do the work in the Analysis Phase. Since analysis is the first Phase, there is little time to train persons for the job. However, it is not always possible to get all experienced people, especially on larger projects, and less-qualified persons may have to be employed. In this case, their need to gain experience and learn may inflate costs or reduce quality.

For the analysis and design effort, availability of information is perhaps the key cost factor. Clear and complete statements of objectives and functions are usually not available and are not provided with all associated information. For example, an analyst might analyze and design an input or output format in half a day, given the appropriate information. However, without the information, he may need days or even weeks to locate and actually obtain the information. For example, the analyst may have to arrange mutually satisfactory conference dates and places, possibly get security clearances, and plan his travel. These support activities require a great deal of the analyst's time--particularly in a large effort in which dozens or even hundreds of questions requiring such efforts may arise.

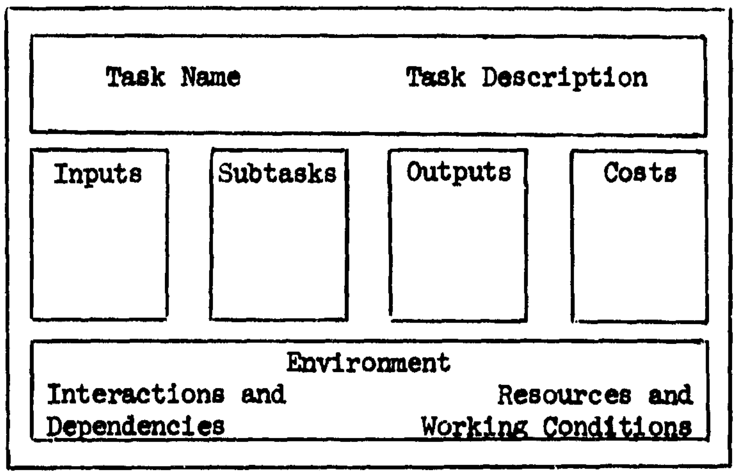
Further, much of system analysis and design work is creative--that is, the information required does not exist but must be generated, e.g., the model of information processing that is needed to design a system. It is extremely difficult to estimate this "cost of innovation." One way is to estimate the amount of new programming and new applications that are in a Project, and find past Projects of a similar nature and study their "innovation" costs.

Incidentally, two major reasons for reviewing old Projects are to avoid "reinventing" and its associated costs and to help the analyst determine the feasibility of an approach. Innovation, or "pioneering," makes meaningful comparison with completed Projects difficult and minimizes the opportunity to learn from experience. For this reason, the cost of doing something for the first time is usually much greater than for subsequent attempts.

Costs of changes made during analysis are less than for those made during any other phase of the program development process. Less work is scrapped, there are fewer elements affected, there are fewer documents to change, and there is much less detail to consider in evaluating a proposed change. Further, if a good job of forecasting is done in analysis, to determine the evolution of the system, fewer costly changes will have to be made. That is, one characteristic of good design is that it can anticipate and accommodate many changes easily.

F. THE CHECK SHEETS

The Check Sheets are organized into a standard format as shown in the following diagram.



Included are the task name and a general description of the task to be performed. The Inputs are redundant in that they indicate both types of information and specific documents containing it that should be available to perform the task. The task is further detailed in terms of subtasks comprising the task. The Outputs or products of the task are, again, redundant, since they are also information or documents that are necessary inputs to succeeding tasks.

Under Costs are factors that should be considered in estimating the cost of performing the particular task. A costing formula or rule of thumb may also be included.

The lower portion of the sheet lists environmental factors, divided into two parts: interactions and dependencies on other personnel and tasks that may cause delays; and some statements about the nature of resources required and the difficulty of obtaining them are included to indicate the degree of difficulty in performing this task.

SYSTEM ANALYSIS TASK 1

PLAN THE PROJECT

INPUTS

Information

User's requirements

User's environment

System requirements

System environment

Production requirements

Production environment

Documents

Project Request

Existing system description

Reports of feasibility studies

Preliminary requirements analysis

Organization charts

Work reports (trip reports, minutes of meetings, feedback letters on conferences and telephone conversations)

Comparative documents (case histories, planning and estimating documents from other projects, cost studies and reports)

SUBTASKS

1. Evaluate available information to determine how much more information must be collected and the probable resource required to collect and analyze it, and make a gross estimate of system size and implementation costs.
2. Collect information from the user and other sources about the proposed and existing systems and their environments, equipment configurations, and modes of operations, and about system production requirements.
3. From an analysis of the information gathered, produce and evaluate a preliminary model of the operational system to determine more precisely system size and difficulty and to evaluate the equipment configuration and usage.
4. Determine Project costs and schedules by preliminary analysis of the system; layout a preliminary program system design in terms of overall functional blocks, and compare the proposed system to similar existing systems. Review all check sheets and complete the Project Summary Sheet.
5. To assess in detail the work to be done, examine each program to be produced to establish program flows, functions, inputs and outputs, and testing requirements, and estimate the man months, computer hours, and elapsed time necessary to produce and test the programs. Complete the Program Planning Sheet.
6. Prepare detailed schedules for the overall Project and for the tasks and components of the system. (See Sections III and IV of the Planning Guide for more detailed discussions of schedule considerations.)
7. Integrate costs, schedules, and other plans by reviewing them among the Project members and with other Project Leaders.
8. Document these plans for the implementation of the program system and obtain the concurrence of management and of the customer. Coordination and concurrence on the Project Implementation Plan should be concurrent with the coordination and concurrence on the Preliminary Functional Description (see System Design Task 6).
9. Publish the Project Implementation Plan.

ENVIRONMENT

Interfaces and Dependencies

Requesting agency, system user, other developers, knowledgeable Project Leaders, and Contract Administration.
Timely delivery of information.
Dependent upon preliminary analysis (see System Analysis Tasks 2, 3 and 4) for completion.
Processing delays in contract administration.
Failure to respond to requests for additional information.
Delay in the decision to contract.
Delays in security clearance and contract arrangements.
Delay in review, evaluation, and approval of costing estimates.

DESCRIPTION

Study the system requirements and estimate the need for manpower, computer time, elapsed time, and other resources. Prepare the Planning Estimates, Project Development Plan and Project Implementation Plan.

OUTPUTS

Information

Elapsed time estimates

Manpower estimates

Computer time estimates

Estimates of number of instructions and programs

Estimates of complexity, innovations, and difficulty

Tentative schedules

Documents

Planning Estimate

Project Development Plan.

Project Summary Sheets

Computer Program Planning Sheets

Schedules

Reports of concurrence

COSTS

1. Adequacy of information received.
2. Availability of proficient ADP analysts.
3. Accessibility of information sources and additional information.
4. Degree of innovation and familiarity of system costed.
5. Delays experienced in getting information and decisions.
6. Size and complexity of system analyzed and costed.

ENVIRONMENT

Resources and Working Conditions

Very small group, easy communications, few trips.

Qualified ADP analysts.

SYSTEM ANALYSIS TASK 2

ANALYZE SYSTEM REQUIREMENTS

INPUTS

<u>Information</u>

(See System Analysis Task 1)

<u>Documents</u>

Project Request

Existing system description

Associated and referenced documents

NAVCOSSACT documents on past systems

Allied projects of other agencies

SUBTASKS

1. Assist user in stating functional requirements.
2. Determine data base manipulation requirements.
3. Determine support system requirements.
4. Determine requirements for program operating time for support and day-to-day operation.
5. Study cost effectiveness and feasibility for critical equipment, including, if necessary, computer facility.
6. Study the user's present system by observations, interviews, and study of available documentation.
7. Discuss ambiguities and problem areas with user personnel.
8. Identify special documentation, phase-over, and/or training needs and problems.
9. Coordinate with other analysis tasks such as "analyze similar systems," "analyze the user's environment" (System Analysis Tasks 3, 5).
10. Document the results of the above subtasks.
11. Review requirements with project personnel and revise as needed.

ENVIRONMENT

<u>Interfaces and Dependencies</u>

User on system requirements.

Other analysts on associated system studies, environmental analysis, production requirements.

Leaders and other evaluation and review personnel.

Timely delivery of complete user requirements.

Need System Analysis Tasks 3 and 5 for information.

Potential delay in requirements review.

DESCRIPTION Determine the operational requirements of the system and evaluate their completeness, feasibility, and compatibility with other systems by studying the Project Request and its references and by contact and coordination with user personnel.

OUTPUTS

<u>Information</u>

Functional requirements

Data base manipulation requirements

Requirements for system support, production support

Modifications to Planning Estimates

Modifications to Project Development Plan

COSTS

1. Accessibility of user personnel and information.
2. Number of trips required to collect data.
3. Number of interviews, conferences, and meetings.
4. Number of documents to read and analyze.
5. Number and complexity of functions in the system.
6. Number of pages of documentation needed.
7. Number of information sources to be contacted.
8. Number of innovations and changes to be analyzed and evaluated for feasibility.
9. Size and complexity of the system.

ENVIRONMENT

<u>Resources and Working Conditions</u>

User's requirements.

Qualified ADP analysts.

Small group, easy communications.

Extensive travel, many conferences, many reports.

SYSTEM ANALYSIS TASK 3

ANALYZE THE USER'S ENVIRONMENT

INPUTS

Information

Descriptions of the user's mission, organization, responsibilities, and projected activities

Customs and rules; procedures for contacting user and industrial personnel and for gaining access to establishments and information

Terminology of the user

Documents

(See System Analysis Tasks 1 and 2)

Organization Charts

Responsibility Charts

Job Descriptions

Standard Operating Procedures

SUBTASKS

1. Gain familiarity with the user's environment, organization, staff, and operating procedures by reading pertinent documentation, conferring with user personnel, and visiting user installations.
2. Write a glossary of user's technical terminology.
3. Determine the organizational elements that will use, operate, and be affected by the proposed system.
4. Determine the functional and organizational areas, present or planned, that will require changes in data processing.
5. Identify and analyze areas needing improvement in the user's present system.
6. Document results of data gathering and analysis.
7. Coordinate results of the analysis with other personnel engaged in analysis.

ENVIRONMENT

Interfaces and Dependencies

Users, installation operations personnel, coordination personnel, and other analysts.

Feeds into System Analysis Tasks 1 and 2.

Need for user to resolve proposed or required changes in organizational structure.

Need to establish the "right and need to know," i.e., in clearing visits to installations and for data dissemination.

DESCRIPTION Study the user's environment and operations, to determine how the system and equipment will be employed, where the operation will be based (ship or shore) and what the responsibilities of the user are, especially to other Naval operations; and to determine the effectiveness and deficiencies of existing data processing operations that might be improved by the proposed system.

OUTPUTS

Information

User's organization description

Responsibilities and mission of user

Operating procedures

List of operational changes

List of operational deficiencies

COSTS

1. Level of experience of user personnel in the application of automatic data processing to his operations.
2. Degree of automation of current data processing operations and/or degree of ongoing analysis and control, application of methods and procedures techniques, and documentation.
3. Amount of travel to dispersed location, number and length of trips to be taken.
4. Number of interviews and conferences.
5. Availability of background information such as familiarity of the user's operation and accuracy and completeness of existing documentation.
6. Number of functions, installations, and operations to analyze.

ENVIRONMENT

Resources and Working Conditions

Small group, some travel.

Operations that are widely dispersed or afloat may be difficult to visit.

Appropriate organization charts, charters, and job descriptions may not exist.

Discovering customs, protocol, and rules of gaining access to installations and information is often difficult for an outsider.

SYSTEM ANALYSIS TASK 4

ANALYZE COMPUTER PROGRAM PRODUCTION REQUIREMENTS

INPUTS

Information

Descriptions of languages, compilers, assemblers, utility systems, monitors, test data generation, and recording and reduction systems

Descriptions of the computers, and other equipment, its machine language and command structure

Reports on EAM, computer and support program usage experience and delivery dates

Details of system to be produced (real-time, relocatable, task-oriented, cyclic vs. stasked job, etc.)

Computer operating procedures

Documents

Project Request

System descriptions

Project files

Manufacturer's equipment manual

NAVCOSSACT Instructions (policies and procedures) on machine requests

SUBTASKS

1. Determine average turnaround and availability of effective time for the computer.
2. Determine project priority during the production period.
3. Examine procedures, schedules, and backlog of EAM shop.
4. Ascertain programming language or languages to be used.
5. Detect and evaluate differences between computer operations for production (e.g., at NAVCOSSACT or contractor) and at the command center.
6. Determine distance and time separation between programming staff and the test computer.
7. Determine procedures for submitting programs for computer run.
8. Investigate utility and support program systems, including print, compile, assembly, etc., to determine reliability, availability, ease of use, and state of documentation.
9. Investigate the monitor or executive system controlling work on the computer, including state of checkout, state of modification, and functional capabilities.
10. Determine actual and potential hardware constraints such as amounts and kinds of storage, input/output devices, displays, etc., that influence the design of the program system.
11. Investigate potential back-up computers and conditions of use.
12. Coordinate with other analysis activities.
13. Advise those producing Implementation Plan and planning for the Indoctrination of Production Personnel (System Design Task 7) on characteristics and limitations of the computer and production tools.

ENVIRONMENT

Interfaces and Dependencies

User, on location and operation of proposed and existing equipment.

Computing operations, on operating procedures and use experience.

Equipment manufacturers, on equipment characteristics.

Software producers, on support program characteristics.

Dependent upon System Analysis Task 2 and 3 for system information.

Potential delay in contacting user and manufacturer for visits and information gathering.

DESCRIPTION Determine the requirements for program production and test, the adequacy of available tools, and the tools required to produce the proposed system by studying the total environment for program production, including computer operations, experience with the project computer and facility, the projected availability of the machine, the availability of back-up equipment, and amount and kind of programming languages, operating systems, and other programming support.

OUTPUTS

Information

Analyses of computer and programming tools

Advice on planned use of computer and tools

Advice on schedules and plans

Descriptions of proposed and available programming tools

Descriptions of computing operations procedures

Changes necessary to adapt existing tools to Project requirements

COSTS

1. Accessibility of user and manufacturing personnel and equipment information.
2. Number of trips needed to collect data.
3. Number of interviews, conferences, and meetings required.
4. Number of computers and supporting gear to be evaluated.
5. Availability and adequacy of documentation on equipment and programming tools.
6. Availability of experienced utility programmers and analysts.
7. Number of pages of documentation to be produced.
8. Costing Formula:

   Senior programmer's time for analysis and documention, estimate: 3 to 9 weeks.

ENVIRONMENT

Resources and Working Conditions

If new computer, precise and current information on computer.

Precise information on computer operations procedures and efficiency.

SYSTEM ANALYSIS TASK 5

ANALYZE SIMILAR AND INTERFACING SYSTEMS

INPUTS

Information

Similar systems in planning, production and use.

Other applicable programs, procedures, tools, and techniques

Documents

Project files

Library files

Planning documents and reports from other projects

Subroutine libraries

Preliminary system design documentation

Proceedings of professional meetings

SUBTASKS

1. Study Project files and reports, and the Catalog of ADP Capabilities (NAVCOSSACT Report 0047) to identify similar systems and extract and evaluate useful facts.
2. Interact with NAVCOSSACT departments, other agencies, organizations, and industry to identify systems that will interface with the projected system, and extract and evaluate the pertinent facts.
3. Identify applicable programs, procedures, techniques, and tools by searching technical books and journals, sources such as the IBM Catalog and SHARE Library listings.
4. Coordinate the results of the search with System Analysis Task 2 personnel.
5. Isolate elements of the projected system, such as routines and data files, that may be available from other projects and systems.
6. Confirm results with command and development personnel who have had experience on similar systems; add to or revise results, and publish.

ENVIRONMENT

Interactions and Dependencies

Personnel of other projects, users and developers of other systems, professional personnel and societies, and contractor and intergovernmental agencies.

Delays in getting data on systems outside NAVCOSSACT (particularly on classified systems).

Delays in getting clearance for access to such data and access facilities of such systems.

Library research often overruns budgets and schedules unless closely monitored.

DESCRIPTION

Determine if there are systems, subsystems, procedures, tools, and techniques already in production or use, or planned, that may influence the current Project or provide useful information for Project plans.

OUTPUTS

Information

Pertinent facts on similar and interfacing systems, and applicable tools, techniques, and procedures

Documents

Reports documenting the above information

COSTS

1. Volume of files and literature to be searched.
2. Efficiency of information retrievel system.
3. Familiarity with the application involved.
4. Number of similar and interfacing systems identified that must be studied and evaluated.
5. Number of briefings, conferences, and interviews to be conducted, both to retrieve and to disseminate information.
6. Volume of documentation to be produced.
7. Costing Formula:

   Estimate 2 to 10 man weeks depending upon the nature of the project.

ENVIRONMENT

Resources and Working Conditions

Considerable searching of files and literature.

Some contact with outside personnel.

Trips and conferences.

Information about systems planned, in production, or in use--frequently vague, general and of limited usefulness.

Adequate and useful summaries of the professional literature seldom readily available.

Personal acquaintances, conferences, and briefings are usually the best sources of information.

SYSTEM ANALYSIS TASK 6

EVALUATE CONTRACT PROPOSALS

INPUTS

<u>Information</u>

System requirements

System environment

Production tools

Interfacing and similar systems

<u>Documents</u>

The Planning Estimate

Reports from System Analysis Tasks 2, 3, 4, and 5

Responses to Requests for Proposals

Directions for evaluating and grading proposals

SUBTASKS

1. Assist contracting agency in preparing system specifications.
2. Assist contracting agency in establishing criteria for evaluating proposals.
3. Assist in evaluating responses to the Request for Proposals.
4. Analyze each contractor's concept for system design and his plan and schedule for production.
5. Recommend contractor selection.
6. Assist in the presentation of briefings on the system to be developed.

ENVIRONMENT

<u>Interactions and Dependencies</u>

Information from System Analysis Tasks 2, 3, 4, and 5.

Contracting agency personnel.

Potential contractors.

See Chart II.

DESCRIPTION

Assist contracting agency in specifying the work to be done, in specifying criteria for evaluation of proposals, and in evaluating the proposals that are submitted.

OUTPUTS

Information

System specifications

Evaluation criteria

Briefings on the system to be developed

Evaluation of proposals and relative scores

Recommendations regarding contractor's approach to system implementation

COSTS

1. Size of the planned system.
2. Type of Request for Proposal (sole-source or solicited).
3. Number of bidders, i.e., number of proposals to be evaluated.
4. Costing formula:

   See Chart estimates range from 8 to 48 man weeks, depending upon the conditions.

ENVIRONMENT

Resources and Working Conditions

Experience in the field of information processing.

Detailed knowledge of user's requirements.

Experience in the evaluation of proposals.

Slow contract proposal and evuation process sometimes requires long lead times.

Pressure to review quickly because of tight schedules.

SYSTEM ANALYSIS TASK 7

ANALYZE REQUESTS FOR SYSTEM CHANGE

INPUTS

Information

Details of proposed system

Details of requested changes

Documents

Requests for design change

SUBTASKS

1. Establish procedures for processing change requests, including the identification of who may initiate, who must authorize their evaluation, who must evaluate, with whom suggested design solutions must be coordinated, and who has the final authority to approve a change.
2. Evaluate design change requests as they occur on the basis of their design merit, importance to the user, effect on schedules, costs, etc.
3. Coordinate the evaluation of design requests with the system designers and implementers.
4. Notify the change requestor of the decision made regarding the change.

ENVIRONMENT

Interactions and Dependencies

Users, on changes in system requirements.

Designers, on design improvements.

Implementers, on evaluations and suggested solutions.

Difficulty in discovering all the implications of changes upon the system.

Design change is perhaps the greatest cause of slipped schedules after delays caused by deferred decisions.

DESCRIPTION

Establish procedures for processing requests for change, and receive, evaluate, and respond to requests for changes in system design.

OUTPUTS

Information

Evaluations of design change requests

Coordination of requested changes

Documents

Change evaluations

Coordination memos to requestor

Design change authorizations

Reports on formal disposition of requests

Changes to plans - Planning Estimate, Project Development Plan, Program Implementation Plan

COSTS

1. The size and extensiveness of the change requested.
2. Relative point in the system development process at which the change is requested. In general, the later in the process the more the cost because of more work scrapped, more work to be done to bring the change up-to-date, and more difficulty in changing, i.e., more decisions needed.
3. The size and duration of the Project, how much might be changed, how much time for system environment to change, how much time for the user to have second thoughts, and how much turnover among users.
4. Costing Formula:

   Experience at NAVOCOSSACT indicates the number of changes averages 4 or 5 for most projects, may range up to 15 for some.

   Each change should be individually evaluated and costed, i.e., work necessary, work scrapped.

   Gross estimates: 5-20% additional for costs, 10-15% for schedules.

ENVIRONMENT

Resources and Working Conditions

Experienced personnel to perform the required analyses, designs, and implementations.

Coordination task, little travel or outside contact necessary except on major changes.

Ease of evaluation depends upon the accuracy and detail of documentation and general knowledge about the system.

SYSTEM DESIGN TASK 1

DESIGN THE TOTAL SYSTEM

INPUTS

Information

Requirements analysis

Environmental and operational analysis

Similar and interfacing system descriptions

Cost and schedule estimates

Documents

Reports from System Analysis Tasks 2, 3, and 5

Planning Estimate

Project Development Plan

Schedules

Budgets

SUBTASKS

1. Interpret functional requirements in terms of equipment, manpower, input types and volume, required response time, and operating environment.
2. Consider alternative ways to satisfy requirements for the total system.
3. Consider interactions among functions alternatively designed.
4. Establish criteria for expected performance based upon objectives.
5. Select a preferred system organization.
6. Note problem areas, decisions required by the user or other non-NAVCOSSACT agencies, and any features whose design requires information not currently available.
7. Produce a system flow diagram.
8. Produce a system design document.
9. Coordinate system design with NAVCOSSACT and user personnel.
10. Revise and issue system design document.

ENVIRONMENT

Interactions and Dependencies

Project and user personnel in the review and evaluation of system design.

Good design depends upon excellent integration of the previous System Analysis tasks.

Potential delays in the review and evaluation of system design documentation.

DESCRIPTION

Develop the total information processing system, and the system configuration that is expected to meet requirements to operate in the user's environment, and produce a system flow chart and system design document.

OUTPUTS

Information

System design

Evaluations of alternative designs

Documents

System design document

System flow diagrams

COSTS

1. Familiarity with system requirements and operations and degree of innovation required to handle them.

2. Amount of new design needed. Usefulness of existing designs.

3. Effectiveness with which earlier tasks are discharged.

4. Size and complexity of requirements.

5. Costing Formula:

   Estimates range from 1 to 3 man months, depending upon the conditions indicated above and the delays experienced.

ENVIRONMENT

Resources and Working Conditions

Complex, highly technical task.

Precision and accuracy of information crucial to good design task.

Availability of appropriate solutions to data-processing tasks requiring innovation, are often costly.

SYSTEM DESIGN TASK 2

DESIGN THE COMPUTER PROGRAM SYSTEM

INPUTS

Information

Total system design (see System Design Task 1)

Similar and related systems discovered in research (System Analysis Task 5)

Computer environment (System Analysis Task 4)

Documents

Total System Design

System flow diagram

Reports on similar systems

Reports on computer environment

SUBTASKS

1. Identify input data characteristics and output requirements.
2. Design and specify the computations, logical manipulations, and transformations to be done within each functional area.
3. Determine the number of programs to be used in performing the required functions.
4. Estimate the size of each program.
5. Diagram the flow of data and functions through the sequence of programs making up the data processing system.
6. Design the data base system.
7. Develop procedures for system data editing, formatting, storing, retrieving, and updating.
8. Reflect requirements imposed by interfacing systems (see System Analysis Task 5).
9. Produce program system design documentation.
10. Revise and coordinate a final version for inclusion in the Preliminary Functional Description.

ENVIRONMENT

Interactions and Dependencies

Interaction requires coordination of analysis personnel and Project Leader attention for design evaluation.

Dependent upon timely delivery and adequacy of program system requirements and the total system design.

Potential delays in internal review of design work and timely decisions regarding design details.

DESCRIPTION

Develop the design for the program system part of the total information processing system.

OUTPUTS

Information

Program system design

Data base design

Documents

Program System Design

Program System Flow Diagram

Data Base Design

COSTS

1. System size and complexity.
2. Degree of innovation and creativeness required.
3. Adequacy of program system requirements and total system design.
4. Experience and skill of available program analysts.
5. Costing Formula:

   Estimated at 10% of the total Project man months.

ENVIRONMENT

Resources and Working Conditions

Creativity, knowledge, experience, and time of the senior programmers, program analysts, and Project Leader.

Complex, highly creative task.

Home office environment, little travel unless major changes must be included.

SYSTEM DESIGN TASK 3

OUTLINE THE PRELIMINARY FUNCTIONAL DESCRIPTION

INPUTS

Information

System design

Data design

Analysis of user's environment

Analysis of production requirements

Documents

Drafts and final versions of documents on system and data base design

SUBTASKS

1. Identify a level of technical detail for the Preliminary Functional Description that will promote the user's understanding of the system.
2. Specify the content components of the Preliminary Functional Description such as:
   - Total System Design
   - Program System Design
   - Implementation Plan
   - Operating Procedures
   - Data Base Design
   - Specification of Interface Requirements
3. Identify the contributors of the components of the Preliminary Functional Description.
4. Schedule the production of the document.
5. Coordinate production plans with the contributors to the document.

ENVIRONMENT

Interactions and Dependencies

All other project tasks that contribute to the Preliminary Functional Description.

Potential delay in the delivery of necessary information.

Potential delay in the coordination of the production plans.

DESCRIPTION

Determine the level of technical detail required in the Preliminary Functional Description, develop the outline of a document to satisfy these requirements, identify those who will contribute to the document, and prepare and coordinate plans for its production.

OUTPUTS

Information

Formats and contents of PFD

Production plans and schedules

Coordination of formats and plans

Documents

Specifications for the Preliminary Functional Description (outline)

Production Plans and Schedules for the Preliminary Functional Description

COSTS

1. Degree of detail required in the analysis of the user's requirements and in the specifications of the document's contents.
2. Number of persons required to review the outline and production plans.
3. Costing Formula:

   Two man days per page of outline and schedule.

ENVIRONMENT

Resources and Working Conditions

Usually a staff job, editorial staff, or technical writing and editing support activity.

Technical writing and graphic arts desirable; editorial and secretarial support required.

SYSTEM DESIGN TASK 4

PRODUCE THE PRELIMINARY FUNCTIONAL DESCRIPTION

INPUTS

Information

System Design

Data Design

Plans for the Preliminary Functional Description

Documents

Drafts and final versions of documents on system and data base design

Drafts of portions of the Preliminary Functional Description

Specifications for the Preliminary Functional Description

Schedules for production of the Preliminary Functional Description

SUBTASKS

1. Write, as part of the total system, program system, and systems files design activities, the component parts of the Preliminary Functional Description.
2. Expedite the production of the component parts of the Preliminary Functional Description.
3. Edit the submitted inputs, as appropriate.
4. Write introduction and integrative chapters and material.
5. Prepare drafts for internal and external coordination.
6. Coordinate and expedite internal review and concurrence.
7. Prepare final coordination draft.

ENVIRONMENT

Interactions and Dependencies

All Project tasks involved in the production of the Preliminary Functional Description.

Duplication facilities; drafting and illustration facilities.

Potential delay inherent in the coordination of the work of many separate activities producing the separate components.

Potential delay in the review and coordination of the draft copies.

DESCRIPTION

Produce and coordinate a document that describes in detail the system to be developed and the environment within which it is to operate.

OUTPUTS

Information

Descriptions of the system to be developed

Internal coordination and concurrence on the Preliminary Functional Description

Documents

Drafts of the Preliminary Functional Description for internal review

Final coordination draft of the Preliminary Functional Description

COSTS

1. Number of pages of documentation to produce.
2. Number of illustrations to design and produce.
3. Number of separate parts to integrate and explain.
4. Number of drafts produced.
5. Productivity rates of those who write, type, review, coordinate, modify, edit, illustrate, reproduce, assemble, bind, and distribute the document.
6. Number of reviewers.
7. Costing Formula:

   Ignoring reproduction and review costs, two man days per page of documentation.

   NOTE: The bulk of the writing and revision costs are included in the costs of other system analysis and system design tasks.

ENVIRONMENT

Resources and Working Conditions

Technical writing and coordination task.

Requires editorial and duplicating support.

Writing skill required. Editorial and graphic arts support is desirable; secretarial and duplicating support required.

SYSTEM DESIGN TASK 5

FAMILIARIZE THE USER WITH THE SYSTEM DESIGN

INPUTS

Information

System requirements

System environment

System design

Documents

All system analysis and system design documentation

SUBTASKS

1. Transmit draft and final system design documents to user and other agencies involved.
2. Promote user understanding of design via meetings, phone calls, letters, and presentations.
3. Confirm the interpretation of user needs and the adequacy of the plans for meeting them.
4. Promote understanding of interfaces with non-user agencies.
5. Identify and promote understanding of data collection called out in the design.
6. Obtain and evaluate feedback.
7. Coordinate results with the program system design and revise designs accordingly.

ENVIRONMENT

Interactions and Dependencies

All other analysis and design activities.

User and allied agencies.

Dependent upon excellence of analyses and design and their timely completion.

Potential delays in making arrangements for briefings and in getting feedback.

DESCRIPTION

Inform the user and other interested agencies, at both working and command levels, of the system design and its expected operation.

OUTPUTS

Information

User understanding of the evolving system design

Interacting agencies' understanding of data collection and other interactions with the system

Feedback on the adequacy of interpretations and designs

Design changes

Coordination of Project plans

Documents

Briefings

Display material

Feedback reports

Change Requests

COSTS

1. Number of contacts, briefings, and conferences.
2. Number of agencies requiring coordination.
3. Sophistication (knowledge and experience level) of user and other agencies in ADP applications to their operations.
4. Size and complexity of system.
5. Adequacy of analysis and design work.
6. Number and length of trips taken.
7. Costing Formula:

   Three man days per design document per agency contacted, plus allowances in elapsed time for travel.

ENVIRONMENT

Resources and Working Conditions

Requires detailed knowledge of total system.

Good public appearance and ability to relate to others.

An ability to communicate clearly and concisely about complex technical subjects.

Many contacts with users--conferences and briefings.

SYSTEM DESIGN TASK 6

OBTAIN CONCURRENCE ON THE PRELIMINARY FUNCTIONAL DESCRIPTION

INPUTS

Information

System requirements

System design

Functional descriptions

Documents

Drafts and final version of the Preliminary Functional Description

SUBTASKS

1. To insure understanding, discuss the provisions of the draft Preliminary Functional Description with appropriate user personnel.
2. Make presentations and briefings, and hold conferences as necessary to insure thorough understanding to resolve difficulties and differences.
3. Coordinate the changes required to resolve ambiguities and correct misunderstandings.
4. Obtain the user's concurrence and approval of the provisions of the Preliminary Functional Description.
5. Publish and distribute Preliminary Functional Description.
6. Document system description for incorporation in official NAVCOSSACT documentation.

ENVIRONMENT

Interactions and Dependencies

Project Leader interacts with user personnel to obtain concurrence.

Project members may interact with user to explain the details of design within their particular areas of responsibility and to assist in the evaluation of recommendations for modifications.

Potential delay in obtaining review and concurrence.

Dependency on the clarity and excellence of the analysis and design.

DESCRIPTION

Present draft Preliminary Functional Description to the user, discuss its contents with him to insure understanding, coordinate the changes necessary to resolve ambiguities, and obtain his concurrence on the details of the system.

OUTPUTS

Information

Briefings, conferences, and presentations

Changes and corrections to Preliminary Functional Description

Concurrence on PFD

Documents

Preliminary Functional Description

Notification of user's approval of the system

Memoranda on changes and corrections

Memoranda recording the results of briefings and conferences

System Description

COSTS

1. Adequacy of prior indoctrination and liaison (See System Design Task 5).
2. Degree of participation of user in the system analysis and design procedure.
3. Technical and editorial excellence of the Preliminary Functional Description.
4. Size and complexity of the system as reflected in the amount of documentation and information that must be considered in the review and concurrence process.
5. Data processing experience of the user as reflected in the amount of indoctrination that must be done and the number of misunderstandings that must be cleared.
6. Remoteness of user, difficulties in communication and contact.

ENVIRONMENT

Resources and Working Conditions

Principally, experience and skill of Project Leader in personal contact and in presenting the details of the design.

Management and coordination task.

Many conferences, personal contacts.

SYSTEM DESIGN TASK 7

INDOCTRINATE PRODUCTION PERSONNEL

INPUTS

Information

Knowledge of the computer programming tools, operating procedures, operating system, etc.

Program system design

Data base design

Formal NAVCOSSACT programming courses

Documents

Programmer manuals

System design documents

Program design documents

Data base documents

Computer manuals

Operating procedures

SUBTASKS

1. Arrange for programmer training in the use of the computer, the computing facility, the programming language, and the compiler, as needed.
2. Train the programmers, as above.
3. Indoctrinate the programming personnel in the use of the system data files.
4. Indoctrinate the programming (and other) personnel in the design of the system and the particular functions for which they are to be responsible.
5. Indoctrinate production personnel in design control and review procedures.
6. Indoctrinate contractor personnel in NAVCOSSACT environment.

ENVIRONMENT

Interactions and Dependencies

Computing facility, on setting up curricula and arranging for computer usage for training.

Equipment manufacturers, on course material.

Utility programmers, for material and lectures.

Other analysis activities for information on the system and programs.

Potential delays in obtaining details about computer, operating procedures, or programming language, or in producing teaching materials pertinent to these.

Dependency upon the timely delivery of system documentation.

DESCRIPTION

Train programmers in the use of the computer and production tools and indoctrinate them in the design and details of the programs to be produced.

OUTPUTS

Information

Understanding of the nature of the programming job and the tools to be used in producing the programs

Lectures and practicum

Documents

Training plans and schedules (curricula)

Manuals

COSTS

1. Experience level of production personnel.
2. Relative familiarity of the computer and programming language.
3. Availability of computer time for training.
4. Number of lectures and practicum scheduled.
5. Changes in system, equipment, or tools design.
6. Costing Formula:

   Without handover (i.e., analysts also do the programming), training costs minimal, but hidden.

   With handover (i.e., new Project members do the coding), estimate one month minimal formal training time per programmer.

   On-the-job training costs not included.

ENVIRONMENT

Resources and Working Conditions

Coordination, teaching activities, staff work.

Experience level of lecturers on computer and programming tools should be high.

Good instructors are often in short supply.

Much training done on the job.

VI. PROGRAM IMPLEMENTATION

The process of producing programs from a set of program system specifications--that is, of implementing the program system design--is divided into three Phases: Program Development, the effort required to design programs that will perform a set of assigned operational functions; Program Coding, the translation of program specifications into program instructions; and Program Checkout, the running of the programs under test conditions to be sure that they are relatively error-free and will perform as specified.

Program Development repeats, on a smaller scale and a finer level of detail, much of the previous analysis and design process, but this process is now focused on the program system component in the information processing system. However, a thorough and accurate job of System Analysis and Design reduces the need to collect additional data in Program Development. To create the detailed designs for many programs during Program Development, the work is usually divided and so requires more people than for System Analysis and Design.

Program Coding, once detailed flow charts or other coding specifications are produced, is a straightforward task. However, even in the Coding Phase, many opportunities for improvement in the detailed design may be detected. In practice, design work does not cease with the coding specifications, but continues not only throughout code production but throughout checkout of the programs. Subject to many errors, coding needs thorough checking prior to program test to detect and remove illegal operators, misspelled and misplaced data references, and errors in logic.

Program Coding is usually done by dividing the programs into many small routines, each of which is coded, compiled, and checked out separately before being assembled into larger blocks and finally into a complete program. A great deal of the work associated with Program Checkout, then, is actually done during this gradual code checking process. No matter how thorough this code checking is, however, it does not entirely guarantee that the program will perform according to specifications either by itself or in combination with other programs. In fact, testing the performance of the individual programs, and of various program combinations, to insure the quantitative performance of the programs, is one of the lengthiest and most important aspects of Program Implementation.

A. OBJECTIVES

The mission of Program Implementation, in general, is to produce computer programs that perform, in a reliable and error-free manner, the data processing functions specified during the System Analysis and Design Phases. Program Development includes the detailed analysis and evaluation of the functions a program is to perform, the design of program logic and a data structure that will perform those data processing functions efficiently, and the specification of that design in a form, such as detailed flow charts, that is readily amenable to coding.

Program Coding includes translation of program design specifications into error-free program code, and detecting and removing design deficiencies as the coding progresses.

Program Checkout includes the thorough evaluation of the code produced, to detect and remove all errors and to diagnose and remedy all operating deficiencies and failures to perform as specified.

B. TASKS

For Program Development, the tasks are:

1. Develop program system test plans
2. Design programs
3. Design program files
4. Establish system files

For Program Coding, the tasks are:

1. Code the programs
2. Desk check the programs

For Program Checkout, the tasks are:

1. Learn the test environment and test procedures
2. Compile and check the program code
3. Test individual programs
4. Test program subsystems
5. Test the program system

On small Projects, all tasks except Program Checkout, Tasks 4 and 5, may be performed by a single person assigned to each program. Project personnel who have designed and coded the individual programs usually have too much ego-involvement in the completed work to be sufficiently critical of its deficiencies in logic or design. To promote objectivity, the inspection, test, and certification of programs and associated documents should be performed by other individuals.

The division of large (10-30 thousand or more instructions) program systems into smaller parts for design and coding creates the need to integrate program parts produced by several people. This need may also arise when programs (designed to run as a system or under a common program monitor) are produced by several organizations. Since testing program systems and subassemblies involves the work of several people, a separate organizational entity for test work can be both efficient and objective. This test crew can design program subsystem and system tests, produce test materials, run tests, and evaluate the results.

In test design, all program paths should be exercised with representative values and some illegalities. This first level in the test hierarchy tests a small unit, e.g., 200 to 2000 machine language instructions that may be a routine or a program. At this level, as few as 25 instructions and as many as tens of thousands of instructions may be tested. For this test, the program is usually operated in a simulated environment and actual outputs are compared with expected results derived or calculated prior to the test. Test plans must specify the program environment, and test designs must specify the inputs and expected outputs based upon the program design. After each test run, the programmer analyzes the results and makes corrections to the code. All corrections must be verified by repeating the program test. The cycle of test, correct, and retest is usually repeated many times before a program operates satisfactorily.

The principal purpose of the program system test is to determine whether or not the computer program satisfies the requirements for operational information processing as described in the Preliminary Functional Description. In developing large systems, subsystem tests may be conducted in a similar manner prior to system test to check performance for only parts of the Preliminary Functional Description. Both simulated and "real" or actual data may be used. Simulated data are preferable for tests requiring close control of the test conditions; real data reflect the vagaries of actual operations and are preferable for testing system reliability and validity. System tests are not usually single, one-shot operations; normally, a battery of "system tests" is used to probe system operation under a variety of conditions. When several versions of the same basic program system exist for use in different operational environments, e.g., different equipment, data base, and functional requirements, many additional system or "adaptation" tests must be run as well as the basic system test. Further, system tests must be repeated each time a major change to the system is implemented or a new version or model of the system released. Hence, a set of well-designed and maintained documents to record system tests may be a permanent asset for continued program system development. The value of these records is further increased by detailing the procedures, techniques, and tools as well as feedback on them.

C. COMMUNICATION, COORDINATION, AND CONTROL

At the time of Preliminary Functional Description (PFD) concurrence, as the Coding Phase begins, the overall program system has been designed, the individual programs have been identified, and a set of documents specifies requirements, functions, and data structures in some detail. It would appear that the work can proceed on the design and coding of the specified programs independently. This is not so. Even with a detailed PFD, the opportunity usually exists for making further decisions about details in the designs of programs that interact with other programs or about the way in which the program and the data will be handled by the user. Therefore, the Project Leader and the Coding Supervisor must coordinate the detailed design work and further monitor and control it to insure that design compatibility among parts of the program system is maintained. To fulfill these responsibilities, the Project Leader must insure that all design decisions and changes are disseminated to all Project personnel.

Specifically, during Program Development, Coding, and Checkout, the Project Leader should coordinate:

- Requirements and plans for use of "real" data for testing, or for joint testing with the user.
- Input and output formats between interfacing programs.
- Communication requirements of programs with the executive or control program.
- Data designs with the central data base and central data file.
- All data and program changes.
- Data file requirements and work with the computing facility.
- Portions of user documentation with all other programs.
- Program changes and corrections with test personnel.
- Requirements for interfaces with other systems--existing or in development, manual or ADP--such as data standards or timing requirements.

The Program Checkout Phase, like the Analysis and Design work, requires a high level of communication and coordination. In doing their jobs, checkout personnel must interact with:

- The program analyst and designers to determine test requirements and to insure that system requirements are stated in a precise and testable way.

- The personnel in the Coding Phase who are developing individual program requirements, designs and test plans.

- The personnel of the EAM and computer operations, to set up procedures to make arrangements for running tests, and to reduce test data for evaluations.

- Responsible programmers, to modify and correct programs during testing.

- Users, to determine testing requirements, to coordinate the use of operational facilities for tests.

During Checkout, the Project personnel depend upon adequate and timely EAM services and computer support, and close cooperation between the machine room and test personnel is mandatory, because slight inefficiencies in procedures that increase turnaround time may seriously slow progress in the Project. Test personnel in the Project need test results as quickly as possible to initiate corrective action when program errors are detected. Interaction with the individual programmers during subsystem and system testing may become difficult and costly if the test facility is separated from the main programming activity by some distance. For example, this separation may slow the development of procedures for modifying and correcting programs quickly or for finding solutions to design problems. Also, arrangements should be made for a special supply of test tapes to record or store intermediate results and to accurately account for the results of several runs of the same programs and tests.

Interpretation of requirements, and arrangements for test data and live environment tests are only a few of the reasons for interaction with the user. To anticipate demonstration and turnover, there may be joint conduct of tests, use of user operators and facilities, and user aid in evaluating test results. Interaction with users and with equipment manufacturers may be needed for joint machine-program integration tests to test the appropriate functioning of both.

D. SUPERVISION

Again, during the Program Implementation activity, the supervisor's task is to monitor all activities and review products. Specific items to be evaluated in each phase are shown below.

Program Development Phase:

- Program system design documentation for sufficiency of detail and quality of design.
- Table designs and file structures for completeness, compatibility, sufficiency of detail and quality of design.
- Individual program designs for completeness, compatibility, quality, and efficiency.
- Storage allocation plans for feasibility, conflicts, potential timing problems, and efficient use of storage.
- Program system test plans for adequacy and accuracy.

Program Coding Phase:

- Program code for conformance to program designs and programming conventions, effective and efficient use of the programming language, adequate use of libraries, and adequacy of commentary.

Program Checkout Phase:

- Test plans and test designs.
- Test results.
- Test documentation and reports.

The Project Leader should try to anticipate and avoid delays of various kinds during Program Implementation. Once under way, this activity is delayed by even a proposed change, e.g., by time spent to evaluate the implications of the change. Any change may result in a considerable amount of work being scrapped as detail designs for processing and data structures are redone and recoded. When the programs reach system testing, the Project Leader should try to defer changes to a later version of the system. To meet schedules, the work should not stop while decisions on changes are being made; therefore, quick decision-making will reduce the costs of changes that require rework.

During the Program Checkout period, many critical, unanticipated difficulties arise that require the supervisor to spend time either solving problems or expediting decision-making by other agencies.

E. COST FACTORS

Little experience data are available on the cost of designing and coding as distinct activities in producing a program. Some expert programmers can produce a detailed flow chart in one day, describe data tables in two days, and write the code in another two days for a relatively simple 1000-instruction program--a total of one man week. With design and code complete, the programmer must now check out the program; and this may require several times as much work. Generally, program design and coding progress by fits and starts as the programmer tries design approaches, sees some improvements, and then reworks his design and code.

The basic tasks such as designing programs, designing tables, and coding programs are most easily costed. The tasks that contribute less directly--planning tests, establishing the central data file, supervising, and documentation--are less readily costed. Some rough rules of thumb are:

Planning tests	One man month per 10,000 instructions *
Designing programs and data	One man month per 1,000-2,000 instructions--more effort when the total system size exceeds 30,000 instructions
Establishing files	One man month per 10,000 items
Maintaining files	One man per month for each 40,000 items
Coding and desk checking	One man month per 5,000 instructions

For program testing, the size, complexity, and degree of innovation of the program system are primary determinants of cost. However, such factors as whether the test facility is conveniently located, the system specifications and test specifications precisely and unambiguously stated, and the test data voluminous and complex can seriously affect test costs and schedules. Tests are needed for each function, each subfunction, and each interaction as well as many joint effects. Since the number and size of tests are difficult to establish before the system has been thoroughly analyzed, prediction of costs is difficult. Computer runs are made to test programs that range between one hundred and several thousand instructions each, and under all sorts of conditions, so that the size and length of individual tests is more difficult to estimate than the number of tests. Some data that represent SDC experience with testing systems are shown below:

* Instructions refer to machine language instructions.

Cost	Range	Average
Computer hours per man month	1-6	4
Computer hours per 1,000 instructions		17
Computer hours per run		0.25
Runs per man month	3-11	5
Runs per 1,000 instructions	3-30	19

F. SCHEDULES

Since Checkout may take 50 percent or more of the total program development time, realistic and detailed scheduling is required. Short-term arrangements are equally as important to long-term schedules. For instance, in scheduling subsystem test runs, the test team should always try to have alternate run sequences laid out in case the planned sequence "hangs up" on a program fault early in the series of runs. If it can be avoided, computer runs should not be scheduled that depend upon the successful performance of any one program, but sets of independent programs and routines should be scheduled. Testing should not come to a halt while the results of a particular test are evaluated, nor should many runs of an apparently successfully operating program be accumulated before test results have been verified.

PROGRAM DEVELOPMENT TASK 1

DEVELOP PROGRAM SYSTEM TEST PLANS

INPUTS

<u>Information</u>

Program system design

System requirements

<u>Documents</u>

Program and system design documents

Preliminary Functional Description

SUBTASKS

1. Develop program, subsystem, and system test requirements based upon system requirements (see System Analysis Task 2).
2. Develop and document a test plan to establish the test environment, including initial data values, configurations of equipment, and setting of switches.
3. Develop and document designs for a series of tests, specifying data paths, illegalities, inputs, and expected outputs and results.
4. Complete Program System Planning Sheet.
5. Review test requirements and design with Project Leader and programmers.

ENVIRONMENT

<u>Interactions and Dependencies</u>

Programmers on test plans and test requirements.

Tendency to delay test planning until program design and coding are underway may retard and degrade effort.

Dependent upon the precision and accuracy of system requirements and system design documentation.

DESCRIPTION

Develop and document program system test requirements, test plans, and test designs to provide the specific plans and criteria for program and system evaluation.

OUTPUTS

Information

Program, subsystem, and system test requirements

Program, subsystem, and system test plans

Program system test design

Documents

Program, subsystem, and system test plans and requirements

Program system test design

COSTS

1. Clarity and "testability" of requirements.
2. Complexity and variety of inputs and outputs.
3. Number of decision points and timing
4. Size and complexity of the system.
5. Costing formula:

   One man month per 10,000 estimated machine instructions.

   Time required to implement test designs (e.g., generate test data) not included.

ENVIRONMENT

Resources and Working Conditions

Requires senior person with test experience; may be the program analyst.

Complex, creative task--requires critical and detailed evaluation of system requirements and system design.

PROGRAM DEVELOPMENT TASK 2

DESIGN PROGRAMS

INPUTS

Information

Program system requirements

Program system design

Data base design

Input/output equipment characteristics

Documents

Preliminary Functional Description

Program System Design and Data Base Design

SUBTASKS

1. Design logic and flowchart each subunit (program) in detail.
2. Specify all input and output message formats.
3. Search program libraries for available subroutines.
4. Coordinate input and output message formats with interfacing programs.
5. Coordinate design and communication requirements with executive control program requirements.
6. Determine data rates and characteristics of input and output equipment.
7. Analyze timing requirements and resolve potential timing problems.
8. Review program designs with supervisor and other programmers and revise designs, as necessary.
9. Write and coordinate program specifications.

ENVIRONMENT

Interactions and Dependencies

Programmers of interfacing programs.

Programmers of executive control program.

Dependent upon timely delivery of precise, detailed, and accurate system and data base design documentation.

Potential delay in the review and approval of program designs.

DESCRIPTION

Design and document the individual programs and routines that have been specified (see System Design Task 2).

OUTPUTS

<u>Information</u>

Program designs

Input/output message formats

Program communication requirements

Timing analyses

<u>Documents</u>

Broad, detailed flow diagrams of each program

Program specifications

COSTS

1. Completeness, accuracy, and clarity of program system designs.
2. Designer's familiarity of area of application (i.e., experience with similar programs).
3. Degree of innovation required.
4. Size and complexity of programs and system.
5. Strictness of timing and storage limitations.
6. Number of logical blocks, dependencies, interfaces, program response requirements.
7. Number and range of inputs and outputs.
8. Mathematical vs. logical tasks.
9. Hardware constraints on program design.
10. Firmness of system design.
11. Experience level of programmers.
12. Costing formula:

    One man month per 1000-2000 machine instructions.

    One man month per 1000 instructions when the program is large (e.g., over 30,000 instructions).

ENVIRONMENT

<u>Resources and Working Conditions</u>

Detailed, creative work. Few external contacts, little travel.

Requires close coordination with other programs.

PROGRAM DEVELOPMENT TASK 3

DESIGN PROGRAM FILES

INPUTS

Information

System requirements

System design

Data base design

Data flows

Input/output requirements

Program specifications

Documents

Design documentation, flow diagrams

Preliminary Functional Description

SUBTASKS

1. Identify the files used or generated by the program that are unique and those that are common to this and other programs, and analyze the flow of data among the programs.
2. Design, for each program, formats of internal tables.
3. Coordinate designs with central data base (see System Design Task 2) and/or other standards or constraints for data elements.
4. Specify, for each program, all inputs and outputs, identifying sources and destinations, formats, and sizes.
5. Allocate blocks of primary and secondary memory for storage of program and data and, if necessary, coordinate storage allocations with the central data base.
6. Review designs with supervisor for accuracy, completeness, and adherence to standards.
7. Coordinate designs with program testing and other activities to insure that forms and formats will permit easy testing and documentation, and allow for possible trade-offs of space for time, etc.

ENVIRONMENT

Interactions and Dependencies

Central data base personnel, on file and table formats and storage allocations.

Program test personnel, other programmers.

Dependency upon preciseness and accuracy of system data descriptions in system designs.

Potential delays in the coordination of table designs and data requirements with central data base and other programs.

DESCRIPTION

Develop and define the form of the data elements to be manipulated by each program, lay out storage allocations, and document program data structures.

OUTPUTS

Information

Formats of internal tables

Specifications for data storage allocations

Documents

Table layouts

Storage layouts

COSTS

1. Amount and variety of data handled by program.
2. Size and complexity of the system.
3. Amount of unique and independent data vs. amount of common, interdependent data.
4. Number of tables, items, files, classes.
5. State of organization, format, and validation of available data.
6. Rate of change of data.
7. Storage and/or timing constraints.
8. Security classification of the data.
9. Costing formula:

   One man month per 10,000 items

ENVIRONMENT

Resources and Working Conditions

Knowledge of large data-base structures--their organization, maintenance, and associated machine storage characteristics.

Detailed, creative task.

Knowledge of standards that may exist for data elements.

PROGRAM DEVELOPMENT TASK 4

ESTABLISH SYSTEM FILES

INPUTS

Information

Program system design

Data base design

Common data structures

Written and verbal data descriptions

Documents

Program system design

Data base design

Flow diagrams

Data description input forms

SUBTASKS

1. Specify central data file structure and conventions of information description.
2. Specify size, coding, and structure of files, tables, and items of common information.
3. Coordinate and document changes, additions, and deletions.
4. Issue periodic reports or listings specifying the current contents of the data files.
5. Use EAM and/or ADP equipment and processes, as appropriate, to create and update the files.
6. If necessary, cooperate with the appropriate programming personnel to create and/or modify the file maintenance programs used to create and maintain the central data tables.
7. Devise and coordinate the procedures for interacting with the central data files and establish schedules and deadlines for the periodic maintenance of the files.
8. Interact with the programmers in defining efficient and appropriate data structures in light of the requirements of the programs using the common data tables.

ENVIRONMENT

Interactions and Dependencies

Programmers, on data structure requirements, and on collection and coordination of data descriptions and structures.

Utility programmers, on creation of appropriate file maintenance system programs.

Dependent upon cooperation with programmers, and upon management support.

Potential delays in programmers' definitions of data requirements and specifications of exact data structures and definitions.

DESCRIPTION

Develop and maintain a central accounting system for information used by more than one program in the program system; document the central data file structure and the procedures for maintaining it; and periodically issue listings of the central file contents.

OUTPUTS

Information

Data structures

Data descriptions

Central data tables

Coordination of data and structures

Efficient common data structures and storage allocations

Control over system data

Documents

Descriptions of central data tables

Instructions for use

Coordination memos

Listing of contents of files

COSTS

1. Size and complexity of common data structures.
2. Size and complexity of total program system.
3. Number of programmers and programs whose data structures must be coordinated.
4. Level of integration of program system and degree of interdependence of programs.
5. Closeness of control required over space and processing time.
6. Degree of responsibility of central data table maintenance operation for controlling space and time efficiencies, and degree of management support.
7. Level of knowledge and skill of personnel in data structure, design, and programmer interaction.
8. Costing formula:

   On small project (2-3 programmers) one person, part time. Estimate one man month per 10,000 machine instructions.

   On large project (over 30,000 machine instructions), two man months per 10,000 instructions.

ENVIRONMENT

Resources and Working Conditions

Production control staff operations.

Only moderate programming skill required.

Thorough understanding of the system, its operation and objectives.

Skill in the design and efficient data structures and in detecting such inefficiencies as redundant data definitions, etc.

Appropriate skill and authority to control data flows and storage allocations, as required.

PROGRAM CODING TASK 1

CODE THE PROGRAMS

INPUTS

Information

Program design details

Coding conventions and standards

Data definition details

Subroutine libraries

Documents

Detailed program flow diagrams

Program design documentation

Data base documentation

Listings and descriptions of available subroutines

User's manual for the programming language

User's manual for the operating system

SUBTASKS

1. Study and understand the program and data base designs.
2. Write coded program statements from detailed flow charts or other program design documentation.
3. Look for common or standard data processing functions and search subroutine libraries for applicable subroutines to insert in the program code.
4. Review program code by looking for:
   - Misspelled, illegal, or missing operation codes and expressions.
   - Undefined, doubly defined, and unreferenced data.
   - Logical errors.

ENVIRONMENT

Interactions and Dependencies

Interact with program designers, if not the same as the coder,

programming supervisor,

central data files personnel.

Dependent upon timely delivery of program design specifications

DESCRIPTION

Translate flow diagrams and other statements of program designs into coded instructions.

OUTPUTS

Information

Coded program statements

COSTS

1. Size and complexity of programs coded.
2. Proportion of new and reused code.
3. Familiarity of the programming language, computer, and operating system.
4. Procedure-oriented vs. machine-oriented language.
5. Experience level of coders.
6. Costing formula:

   Gross estimate at one man month per 5,000 instructions.

   Estimate that 2,000 procedure-oriented language statements are roughly equivalent to 10,000 machine-language instructions.

ENVIRONMENT

Resources and Working Conditions

Less experience and skill required than for program design or analysis.

Usually performed by those who design the programs.

Relatively straightforward task, some room for creativity and cleverness.

PROGRAM CODING TASK 2

DESK CHECK THE PROGRAMS

INPUTS

Information

Program listings

Program design details

Coding conventions and standards

Data definition details

Documents

Program flow diagrams

Program specifications

Data description listings

User's manuals for the programming language and computer operating system

SUBTASKS

1. Obtain a keypunched and verified symbolic program listing.
2. Review (desk check) program listing for errors, checking for illegal expressions, coding mistakes, and data errors.
3. Compare program code to program flow charts to be sure that all functions are completely coded and to trace the logic of the program to be sure that no logical errors have occurred.
4. Obtain an independent review of the program from either the programming supervisor or a senior programmer.
5. Correct all illegalities and reprogram the logical errors and inefficiencies that were detected.
6. Review (desk check) the code of other programmers to detect illegalities, logical errors, and programming inefficiencies.

ENVIRONMENT

Interactions and Dependencies

EAM, and other computing facilities.

Programming supervisor and/or senior programmers in reviewing the adequacy and correctness of the program code.

Dependent upon the timely production of code.

Potential delay in slow turn-around time in the keypunching and listing of code.

Potential delay in obtaining supervisory and other reviews of program code.

DESCRIPTION

Desk check program code by looking for illegal expressions, erroneous data referenc(, program logic errors, programming inefficiencies, and deviations from program specifications.

OUTPUTS

Information

Assurance of coding quality

Detection of program errors

Documents

Desk checked symbolic program deck and listing ready for compilation

COSTS

1. Size and complexity of programs checked.
2. Proportions of unfamiliar and difficult code.
3. Familiarity with the programming language, computer, and operating system.
4. Procedure- vs. machine-oriented language.
5. Experience level of checkers.
6. Excellence of code checked in terms of being well-organized, easily understood, free from errors, and simple.
7. Costing formula:

   Cost included in the effort to produce the code (see Program Coding Task 1).

ENVIRONMENT

Resources and Working Conditions

Usually performed by those who write the code and by the programming supervisor or leadman.

Requires c nsiderable knowledge of programming techniques and of the coding conventions and standards established for the Project.

Tedious, mechanical task, calling for a sharp and critical eye in detecting errors and inefficiencies in program code.

PROGRAM CHECKOUT TASK 1

LEARN THE TEST ENVIRONMENT AND TEST PROCEDURES

INPUTS

Information

Computer room procedures

Computer availability

Computer program test procedures

Special project procedures

Documents

Utility and support program descriptions

Equipment manuals

SUBTASKS

1. Learn the computer room procedures, paper work required, turnaround time, priority system, test decks, and test data identification.
2. Learn the characteristics of the utility system, support programs, monitor system, and test data generation, recording, and reduction programs.
3. Identify the various positions that must handle a job submitted for machine processing and where delays may occur.
4. Learn the procedures for retiring test decks and test tapes.
5. Become acquainted with computer operations personnel.

ENVIRONMENT

Interactions and Dependencies

Computer operator personnel,

Couriers or messengers.

Complexity and size of data base.

Timely access to computer room personnel and availability of procedures.

DESCRIPTION

Using test requirements as a framework, learn the procedures for using the computer, the utility system, and other support systems.

OUTPUTS

Information

Ability to use procedures, compilers, computers, and programming support tools

COSTS

1. Adequacy of documentation of computer room procedures and test procedures.
2. Programmer experience with the computer facility.
3. Adequacy of documentation of equipment, and utility and support tools.
4. Stability (few changes) in the programming tools and the control programs, and rapid communication of any changes.
5. Costing Formula:

   One man week per programmer.

ENVIRONMENT

Resources and Working Conditions

Programmer test experience .

Mostly on-the-job training; little documentation of procedures; relatively straightforward task .

PROGRAM CHECKOUT TASK 2

COMPILE AND CHECK THE PROGRAM CODE

INPUTS

Information

Identification of language type

Instructions required for assembly or compilation

Documents

Program deck in the form of symbolic cards

Assembly or compiler program

Computer Job Request

SUBTASKS

1. Submit first block of symbolic code for compilation with appropriate job request.
2. Prepare subsequent blocks of code while waiting for the results of compilations, until all blocks are in process.
3. Receive print-outs of compilations and modifications and desk check for grammatical and logical errors.
4. Correct errors; repunch cards, as required; produce new deck or tape; and modifiy, reassemble, or recompile program as appropriate.
5. Assemble subblocks of code into larger blocks until program or routine is compiled as a completed unit.
6. Store correct program in binary form in program card file and/or on system tape for testing.

ENVIRONMENT

Interactions and Dependencies

Computer operator personnel.

Couriers or messengers.

Utility or operating system .

Reliability of computer and utility programs.

Competition with other machine users.

DESCRIPTION

As individual blocks of code are written in either symbolic assembly language or procedure-oriented language, assemble or compile each block into machine-readable (binary) form, check the listings for errors, correct the code and recompile, continuing this process until a satisfactorily compiled program or routine is obtained.

OUTPUTS

Documents

A program in binary, available on cards, tape, and print-out, ready for program testing

COSTS

1. Availability of reliable assembler or compiler and accurate documentation.
2. Availability of computer time and EAM support.
3. Programmer experience.
4. Costing formula:

   Computer time rule of thumb for compiling with JOVIAL*
   average 150 statements/minute
   range 75-300 statements/minute**

*TM-WD-147/000/00 describes the operation and use of this JOVIAL compiler.

**Note that these statements generate both instructions and data.

ENVIRONMENT

Resources and Working Conditions

Adequate diagnostics and understanding of the compiler.

Computer time and operator skill.

PROGRAM CHECKOUT TASK 3

TEST INDIVIDUAL PROGRAMS

INPUTS

<u>Information</u>

Program test plans, requirements and schedules

Program requirements and designs

<u>Documents</u>

Program Design Specifications

Program Test Plan and Test Design including input test data specifications and expected outputs

Program Environment Specifications including system data tables, other programs, and executive or control program

Program Symbolic Deck, Binary Deck, Listing, and Memory Allocation Chart

Program Change Requirements

SUBTASKS

1. Review and evaluate program test plan that specifies test environment. (See Program Development Task 1.)
2. Develop and document program test design that specifies inputs and expected outputs, data paths, and illegalities.
3. Produce test data required by test design.
4. Run program using simulated inputs and environment and test for expected outputs.
5. Develop recording specifications as needed.
6. Document results of the program test and error corrections.
7. Write, coordinate, publish, and distribute a complete description of the program.

ENVIRONMENT

<u>Interactions and Dependencies</u>

Program designers and system designers.

Computer operator personnel.

Subsystem Test activities.

Coding activities.

Other subsystem developers.

Reliability of computer and software.

Computer turnaround time.

Unscheduled computer maintenance.

Competition with other computer users.

DESCRIPTION

Within the requirements set forth by general plans and requirements for program testing (see Program Development Task 1), plan, design, produce, and run performance tests of the individual programs to isolate and correct errors, rerunning the tests untill all program requirements and design specifications are satisfactorily met.

OUTPUTS

__Information__

Program test designs, test data, and run results.

Recommendations for future program modifications

Recommendations for approval or deferral of requirements and design features

Assurance of program quality

__Documents__

Documentation of designs and tests

Reports of run results and actions taken

Memoranda on recommended changes

Program Descriptions

COSTS

1. Availability of computer: total computer time and turnaround time.
2. Availability of programming tools and descriptive documentation.
3. Adequacy of test planning and design.
4. Number of instructions in program to be tested.
5. Number of inputs and outputs.
6. Extent of innovation and complexity in the program design.
7. Number of program design changes to be implemented.
8. Extent of procedural documentation.
9. Costing formulas:

   Anticipate one error per thirty instructions.

   All testing requires between 40-50 percent of total development efforts.

   Program test requires about 20 percent of the testing effort.

ENVIRONMENT

__Resources and Working Conditions__

Continual interaction with the computer and attendant delays require careful planning of programmers' time. Delays may be used for parallel activities such as documentation, replanning, and study.

Programmer experience in testing, test planning, and designing.

Computer time.

Support programs (testing tools).

PROGRAM CHECKOUT TASK 4

TEST PROGRAM SUBSYSTEMS

INPUTS

<u>Information</u>

Program subsystem test plans, requirements and schedules

<u>Documents</u>

Program System Design Specifications

Program Subsystem Design Specifications

Program Design Specifications

Program Subsystem Test Plan and Test Design including input test data specifications and expected outputs

Decks of tested program(s) that constitute the subsystem

Data Base Design Specifications

Program Subsystem Environment Specifications including other subsystems, executive or control program

Program Test Results

Program Subsystem Change Requirements

SUBTASKS

1. Review program subsystem test plan that specifies test environment. (See Program Development Task 1.)
2. Develop and document program subsystem test design that specifies inputs and expected outputs, data flows, and illegalities.
3. Put programs that constitute subsystem together.
4. Produce test data required by test design.
5. Run program subsystem test using simulated inputs and environment, and test for expected outputs.
6. Document error corrections and evaluate results of program subsystem test.

ENVIRONMENT

<u>Interactions and Dependencies</u>

Program designers and system designers.

Computer operator personnel.

Program test activities.

Reliable computer and software.

Computer turnaround time.

Unscheduled computer maintenance.

Competition with other computer users.

DESCRIPTION

Within the context of the more general program system test plans, design, produce and run program subsystem tests for physical integration of functionally interdependent blocks of programs to isolate and correct failures of functional interactions and failures to meet program specifications.

OUTPUTS

<u>Information</u>

Subsystem test designs, test data, and run results

Recommendations for future subsystem modifications

Recommendations for cancellation, modification, or deferral of requirements and design features

Assurance of satisfactory program interactions in the subsystem

<u>Documents</u>

Documentation of designs and tests

Reports of run results and actions taken

Memoranda on recommended changes

COSTS

1. Availability of computer: total computer time and turnaround time.
2. Availability of programming tools and descriptive documentation.
3. Availability and accuracy of raw test data.
4. Adequacy of test planning and design.
5. Number of instructions in program to be tested.
6. Number of inputs and outputs.
7. Extent of innovation and complexity in the program design.
8. Number of program design changes to be implemented.
9. Extent of procedural documentation.
10. Number of displays in subsystems.
11. Costing formula:

    Varies between zero and thirty percent of total testing effort depending on number of subsystems.

    All testing requires between 40-50% of total development effort.

ENVIRONMENT

<u>Resources and Working Conditions</u>

"Subsystem," "task," "string," or "assembly" testing usually involves considerable pressure, relatively long computer runs, late hours, and many conferences on catastrophic program failures and emergency changes to plans and schedules brought about by unexpected failures, delays, and changes.

Programmer experience in testing, test planning and designing.

Computer time.

Support programs (testing tools).

PROGRAM CHECKOUT TASK 5

TEST THE PROGRAM SYSTEM

INPUTS

Information

Program system test plans, designs, data, and schedules

Documents

Program System Design Specifications

Program System Test Plan and Test Design including input test data specifications and expected outputs

Program System Environment Specifications including system data tables, executive or control program

Program System Symbolic Deck, Binary Deck, Listing, and Memory Allocation Chart

Program Subsystem Test Results

Peripheral Equipment Operating Descriptions

SUBTASKS

1. Review program system test plan and design--revise as needed. (See Program Development Task 1.)
2. Integrate program subsystems for program system test.
3. Run system test with simulated and/or real inputs and environment and test for expected outputs.
4. Document the results of the system test and error corrections.
5. Rerun corrected program system and test for expected outputs.

ENVIRONMENT

Interactions and Dependencies

Program designers and system designers.

Computer operator personnel.

Subsystem test activities.

Turnover and Demonstration activities.

Other system developers.

User personnel.

Peripheral equipment.

Dependency on reliable computer, software, and peripheral equipment.

DESCRIPTION

Within plans for the overall quality assurance of the program system, design, produce, and run tests (usually consisting of a series, or increasing size and complexity) of the total program system to isolate and correct system malfunctions.

OUTPUTS

Information

Program system test data and run results

Recommendations for future program modifications

Recommendations for approvals or deferral of requirements and design features

Assurance of program system quality

Documents

Documentation of designs and tests

Reports of run results and actions taken

Memoranda on recommended changes

Program System Description

COSTS

1. Availability of computer: total computer time and turnaround time.
2. Availability of programming tools and descriptive documentation.
3. Adequacy of test planning and design.
4. Number of instructions in program system.
5. Number of inputs and outputs.
6. Extent of innovation and complexity in the program design.
7. Number of program system design changes to be implemented.
8. Extent of procedural documentation.
9. Number of displays in subsystems.
10. Extent of innovation and complexity in the system design.
11. Number of system design changes.
12. Extent of concurrent system development.
13. Number of organizations involved in system test.
14. Adequacy of realistic test data.
15. Costing formula:

    About 50% of total testing effort.

    All testing requires between 40-50% of total development effort; therefore system testing comprises about 25% of the total effort.

ENVIRONMENT

Resources and Working Conditions

Programmer experience in testing, test planning, and designing.

Computer time.

Support programs (testing tools).

A great deal of coordination and communication are required to complete system test; therefore, adequate planning is essential.

Distinction between errors in hardware and software is at times very difficult.

VII. SUPPORT AND TURNOVER

The last set of Phases in the program system development process are those associated with preparing for and making the delivery of the system to the user. This includes preparing operating and maintenance manuals, helping the user prepare to operate the system through training and assistance, conducting the demonstration trials, and working closely with the user during the period of shakedown to detect and correct any remaining program errors.

The tasks associated with support of the user, although sometimes viewed as an imposition by those interested solely in the design and coding of computer programs, are an extremely important activity from the managerial point of view. The perceived success of the Project may rest upon how well the user understands his new system. Therefore, it is "good business" to provide the user with adequate information in the form of documentation, training (including practice in the use of the system), briefings, and other customer-relation services. Such services may include advice and consultation on procedures, organization, and operations.

A. OBJECTIVES

The mission of the Support and Turnover Activity is to prepare the user to receive and operate the system, and to change his mode of operation as needed to fit the new system.

In the User Documentation Phase, the objective is to develop and produce a set of instructional manuals that will best help the user to understand, operate, and maintain the program system.

In the User Training and Assistance Phase, the objective is to ease the user's transition into the new mode of operation. This is done by (1) building or redefining his data stores and associated data-handling procedures, (2) redefining work organization and procedures, (3) providing assistance to create understanding of the system's capabilities and (4) promoting acceptance of the new mode of operation.

In Turnover, the aim is to help the user demonstrate, to his own satisfaction, that the system will operate as specified, and to support the user with advice, guidance, and immediate trouble-shooting during the initial period of system operation.

B. TASKS

For User Documentation, the tasks are:

1. Verify the completeness and accuracy of the program system specifications.

2. Outline user documentation.
3. Produce user documentation.
4. Obtain concurrence upon user documentation.

For User Training and Assistance, the tasks are:

1. Advise user on data collection and conversion activities.
2. Develop a user training plan.
3. Conduct training program for user's staff, operator and maintenance personnel.

For Turnover, the tasks are:

1. Develop the Turnover Plan.
2. Conduct demonstrations.
3. Assist in the operational shakedown of the system.

Although the Project Leader must always plan on Project participation in the Support and Turnover activity, the amount of work required will depend greatly upon (1) the past experience of the user in applying ADP to his operations, and (2) the extent and complexity of the interaction between human operators and the ADP system. If the computer is used completely off-line, and the user is familiar with ADP operations, Project personnel will have to supply little support. However, if operation is completely on-line and dynamic, and involves a completely naive user, much training and support may be required.

User documentation is a particularly important deliverable product, since the operation of the system will be very difficult to learn without adequate descriptive material. To the extent possible, user documentation should be adapted to the needs of each user. For example, a standard set of documents for an off-line system may include using guides and procedures for operators but an on-line, real-time system requires much more documentation of this type such as instructions for each different operating position (sometimes called Positional Handbooks).

At NAVCOSSACT, the user is responsible for a very important task, i.e., the collection and conversion of data files to be used by the system, including the formulation of data collection and distribution procedures for use during system operation. If the user is unfamiliar with ADP, however, he may need considerable guidance in setting up files and establishing and implementing procedures. Also, the inexperienced user may be unaware of the stringent demands for precision, accuracy, and completeness in data to be used in computer systems. In such cases, the first compilation of data will probably not work without a great deal of editing and correction.

A breakdown of the data collection and conversion tasks expected of the user is:

1. Determine the types, forms, and structures for data needed as inputs for the ADP.
2. Identify the sources of the specified data.
3. Determine the volume and frequency of arrival of various data elements.
4. Determine or establish appropriate data collection procedures and forms, for both the initial and ongoing collection of data.
5. Collect data.
6. Verify data accuracy and completeness.
7. Manually process data by entering them on data forms (properly placed, scaled and arranged); by keypunching; by inspecting listings; and by manually controlling card files and listings.
8. Convert and store data in the specified storage medium, using the computer and computer programs provided for this purpose.
9. List stored data and inspect the results to verify the correctness of the data as stored.
10. Turn over the converted data base files to operational personnel.
11. Prepare, if required, simulated data base files and other test data.
12. Cooperate in testing by inspecting the results of tests to detect processing and data errors.
13. Specify requirements for data base load and maintenance programs.

Although the Turnover tasks stress the intangible activities such as coordination, consultation, training, indoctrination, and communication, the Turnover Plan may be accompanied by other tangible products, e.g., briefing documents, conference reports, test materials, and training materials. At NAVCOSSACT, the Turnover Plan must be completed not later than one month before the completion of Program Checkout.

On small Projects, the Project Leader or another Project member performs the Turnover tasks, particularly coordination, monitoring, and briefing. Checkout personnel do the planning, design, production, and actual conduct of demonstration tests. Usually analysts and programmers in the Project train and indoctrinate user personnel. On a large project, however, and especially one with many ADP centers requiring multiple installation of the program system, special Turnover or installation teams will be needed to coordinate with the user, to adapt the program system (e.g., introducing a new data base for each location), to indoctrinate and train the user, and to develop and conduct the demonstration tests.

C. COMMUNICATION, COORDINATION, AND CONTROL

Much of the support activity insures that the plans made by the user and the developer are integrated, and that the schedules are met. During the User Documentation Phase, once documentation plans are firm, the main coordination task concerns changes to the system, i.e., to assure that the statements in the documents are current and accurate.

For the data base work, Project personnel must insure design and schedule compatability for easy combination of the program system and the data base. Any decisions that extend or alter the basic data base design should be promptly transmitted to the user so that he can reflect them as necessary in the data base. Also, the responsibilities and work load of the data base team--e.g., ease of data collection and conversion and availability of time to respond to changes--must be considered in making any changes. Missing data may seriously affect the data base design and impose unexpected requirements on the programs. Again, equipment design that may differ from that expected constrains data base manipulation; e.g., precision , speed, and reliability of data handling may be reduced from that originally specified. Data may have to be estimated or interpolated to obtain the desired precision, or design requirements may have to be changed. These situations point up the need for close coordination between the data base and program design activities.

Turnover is a crucial phase because the user may readily find fault with the system unless he thoroughly understands it and accepts its limitations as well as its advantages. This is a period of transition for the user. From the familiar--the safe, secure, and stable, with introduction of a new program system, he enters into the unknown and uncertain. He may be anxious and ready to find fault with the system. To remove this uncertainty and insecurity, the Turnover team must try to continue to communicate freely and easily with him.

The Gantt Chart in Section 3 shows that the time interval for the Turnover Phase overlaps, to a considerable extent, the intervals for the entire Checkout Phase and even the final stages of the Coding Phase. If Turnover is handled by a separate team, their early work includes intense study of the details in both the design and planned operation of the system. The team uses this knowledge to plan the Demonstration test and to indoctrinate the user.

In addition, Turnover personnel must adopt and maintain a system orientation, i.e., they must understand and treat the system as a unit, and they must try to pass this orientation on to the user. While many of the minor operations of the system may go wrong or be found in error, these discrepancies must be viewed and weighed within the framework of the total system.

Although it is desirable to forbid or defer design changes at this stage, such changes may be needed and implemented, and consequently may disrupt Turnover. As an alternative to implementing such changes, a suggested technique is to set up the "two-tape" system for the user (that he will undoubtedly need after he assumes responsibility for program system maintenance). In such a system the basic tape is not changed, but all changes, e.g., changes in requirements or corrections of discrepancies, are introduced in a follow-on version of the "system tape." Then they will be ready for system testing as soon as the prior version is released for provisional use. This two-tape technique is also good for system maintenance and could be handed over to the customer with the system. Without the protection afforded by this technique, the inexperienced user may introduce changes into the operational version--changes that have not been thoroughly tested and so may foul up his system, possibly at a crucial time in operations.

D. SUPERVISION

The products that must be reviewed by the supervisor during the Support and Turnover Activity are:

- Revisions of program specifications.
- Plan for, outline of, and drafts of user documentation.
- Training plans.
- Turnover plans.
- System changes for both programs and data base.

Support and Turnover activities demand frequent contact with the customer, e.g., in the form of briefings and conferences. To insure good customer relations, as well as good performance in other tasks in this phase, the Project Leader may personally make these customer contacts.

E. COST FACTORS

Although the costs of the mechanics, i.e., writing, editing, and reproducing a document, are fairly well known, the separation of these costs from the cost of doing the more creative part of documentation is not. That is, the cost rules, unrealistically, assume that this mechanical production of the document is done after or independently of the thinking and information-gathering work needed to generate the information going into the document. Since this is not usually the case, the Project Leader must estimate and account for these costs as well. If these costs were separable, the costs of the creative work would likely exceed those of production work.

The cost of Data Collection and Conversion itself depends largely upon the amount, i.e., the total number of items, complexity, number of different item types, the rate of change of data, and the number and accessibility of data sources. Another factor that adds to the cost is the handling of classified data. In a NAVCOSSACT Project, the cost of advising and monitoring the data base activity will vary between one and sixteen man weeks, depending upon the size and length of the data collection activity. Once communication channels and procedures have been established, junior personnel can usually be assigned.

"Assisting the user in preparing (and conducting) a demonstration test" can be a costly operation. Two factors have a heavy influence on costs; (1) the user's inexperience with ADP, and (2) the dispersion and variation of program system, e.g., in case it must be installed in several locations with differing equipment and program configurations, environmental conditions, and system interfaces. A successful demonstration depends upon thorough study of environmental differences with emphasis upon current, reliable, and detailed information. "Dry runs" prior to demonstrations help to expose and eliminate many problems that might occur during the Demonstration and also to expedite the education of users.

Costing such intangibles as coordination, consultation, and indoctrination is difficult. Experience shows that any funds allotted to this activity are profitably spent. Any lack of funds usually reduces the work on the "soft" tasks, the educational and consultation efforts, while funds for the "hard" tasks, actual Demonstration test development and running, remain adequate. Such poorly balanced funding for Turnover results in a more difficult self-indoctrination and shakedown period for the user. Therefore, rather than risk customer dissatisfaction, it is best to budget time and resources for coordination, consultation, and indoctrination.

F. SCHEDULES

In scheduling documentation, try to begin early enough to influence the final production of program specifications and pace it to match the development of the programs. During system testing, the availability of documents, even if only in rough draft form, is crucial. Polished, formal documents should be delivered at the time of system demonstration and sign-off as part of the delivered system. Of course, the documents will have been reviewed and approved before that date. On the other hand, during system shakedown, minor discrepancies and inefficiencies may be uncovered in both the programs and documents. Therefore, the format of the documents should permit changes to be made to the delivered final versions of the documents so that the system can begin operations with a "clean deck," in both documents and programs.

As implied earlier, close coordination of data base design and maintenance is essential for compatible schedules. For example, the Data Collection and Conversion task depends upon the data base design work. Also, if "real" data from the data base are to be used in program testing, delays in data gathering or difficulty in constructing the data files can slow testing. Realistic schedules are important because delays during testing can endanger the entire development cycle and little opportunity exists to add personnel, since they would require education on the entire Project work to date.

Turnover and Shakedown schedules may be endangered by all sorts of delays, particularly in tasks involving interaction with the user. Coordination itself takes time. For example, although the development of a training curriculum is not usually a problem, securing agreement with the user for a training schedule may be. The Project Leader should allow time for the user staff to review and modify proposed schedules and for coordination of all plans that involve user participation.

USER DOCUMENTATION TASK 1

VERIFY THE COMPLETENESS AND ACCURACY OF THE PROGRAM SYSTEM SPECIFICATIONS

INPUTS

Information

Details of the program and program system design specifications and requirements

Data base designs

Changes to the system

Documents

Preliminary Functional Description

Program system design specifications

Program design specifications

Data base design specifications

Flow charts

Design change documentation

SUBTASKS

1. Collect copies of all previous system documentation such as:
   - Preliminary Functional Description
   - Program system design specifications
   - Program design specifications
   - Program flow charts
   - Data base design specifications
   - Changes to the system
2. Review documentation to insure its accuracy and completeness and to evaluate its adequacy for use in the production of user documentation.
3. Check with system and program design personnel to be sure that documents are correct, complete, and up to date.
4. List missing information and interview programming and design personnel to obtain it.
5. Collate the documents and information collected and produce drafts of specifications and flow charts that reflect current information.
6. Coordinate the revised specifications with the appropriate programming personnel to verify the accuracy of the information.
7. Incorporate corrections and clarifications into the draft specifications.

ENVIRONMENT

Interactions and Dependencies

Programmers and analysts in collecting program specification information and verifying its accuracy and completeness.

Dependent upon the timely completion and quality of program documentation.

Potential delay in getting current information from individual programmers.

Potential delay in the review and coordination of the revised specifications.

Potential delay in resolving last-minute program changes.

DESCRIPTION

Verify the accuracy and completeness of program system documentation, and produce drafts of current, up-to-date specifications.

OUTPUTS

Information

Verification of the accuracy and completeness of program system documentation produced as working drafts

Documents

Drafts of updated specifications

COSTS

1. Amount and complexity of the previous system documentation.
2. Accuracy and completeness of the documentation.
3. Number of changes to be incorporated.
4. Number of reviews of coordination drafts.
5. Costing formula:

   Technical review: 20 pages per man day
   Revise: 10 pages per man day
   Collect Information: 2 days per document plus 2 hours per interview
   Type: 20 pages per man day

   At least two drafts of the revised specifications should be expected.

ENVIRONMENT

Resources and Working Conditions

Technical editing and writing personnel.

Programming specifications often tend to be vague and incomplete, and subject to many undocumented changes.

USER DOCUMENTATION TASK 2

OUTLINE USER DOCUMENTATION

INPUTS

Information

Details of program and program system design and data base design

Details of user documentation requirements

Documents

Drafts of current program specifications

Program flow charts

SUBTASKS

1. Review current drafts of program specifications, flow charts, work sheets, and other documentation to determine the scope and nature of the program system to be documented (see User Documentation Task 1).
2. If necessary, confer with user concerning his documentation requirements to determine the number and kind of documents to be produced and the way in which the documents will be used.
3. Prepare outlines of the proposed user documents, including:
   - Staff Manual
   - Technical Operations
   - Program System Maintenance
4. Determine, if possible, the illustrations and charts to be included in the document.
5. Coordinate the outlines and illustration lists with programming and user personnel to insure completeness and appropriateness.
6. Coordinate with technical illustrators for elapsed time and schedule considerations.
7. Plan the production of the user documentation, including schedules and work estimates, and identify sources of information and material.
8. Distribute the user document outlines or specifications and production plans to the appropriate persons.

ENVIRONMENT

Interactions and Dependencies

Programmers, to insure completeness and appropriateness of documentation outlines and plans.

User, to determine documentation requirements and the adequacy of proposed documentation.

Dependent upon quality and availability of prior documentation.

Potential delay in determining user's requirements for documentation, if these are other than those normally produced.

Potential delay in the review and coordination of plans.

DESCRIPTION

Determine user documentation requirements and the scope of the system, outline appropriate user documentation, plan its production, and issue user documentation specifications and production plans.

OUTPUTS

Information

Determination of user documentation requirements

Specification of user documentation

Coordination of specifications and plans

Identification of contributors

Documents

Outlines or specifications for user documentation

Schedules for production of user documentation

COSTS

1. Size and complexity of the system.
2. Quality of prior documentation.
3. Experience level of user in ADP applications and required user's manuals.
4. Number of coordination and review points for plans and outlines.
5. Costing formula:

   Approximately two man weeks per user's document, plus writing and editing costs of producing outlines and plans. (Assumes each major function requiring one operator's attention results in one user document such as a guide or handbook)

ENVIRONMENT

Resources and Working Conditions

Technical writing and editing capability.

Programming documentation often inadequate and incomplete.

USER DOCUMENTATION TASK 3

PRODUCE USER DOCUMENTATION

INPUTS

Information

Details of program system and data base design

User documentation requirements

Formats and outlines of user documents

Documents

Prior system documentation

Current drafts of program specifications

Outlines and specifications of user documentation

Schedules for the production of user documentation

SUBTASKS

1. Assign personnel to the writing, editing, and illustration of the user documentation.
2. Coordinate the production of the different parts of the user documentation to ensure that schedules are met and that document contents are compatible.
3. Write introductory and integrative material to insure cohesion and continuity in the document.
4. Prepare indexes and glossaries as needed.
5. Collect, edit, and integrate drafts of the various parts of the user documents.
6. Prepare coordination drafts of the user documents and circulate them for review and coordination by users and program development personnel.
7. Collect commentary and revise user documentation to produce final concurrence draft.
8. Coordinate the production of the user documents with Turnover personnel to determine training and demonstration requirements for user documentation and to arrange for the practical evaluation of user documentation during demonstration and shakedown.
9. Coordinate the mechanical production of the document to insure schedules are met.

ENVIRONMENT

Interactions and Dependencies

Programmers and analysts, on producing portions of the user documentation and coordinating drafts.

User personnel, in the review and coordination of draft documents.

Turnover personnel, in determining training and demonstration requirements and arranging for evaluation of the documents.

Dependent upon the timely completion and delivery of the parts of the documentation produced by many contributors.

Potential delay in review and coordination of drafts.

Potential delay in changes to the documentation to incorporate program changes.

DESCRIPTION

Perform the technical writing and editing necessary to produce user documentation, coordinate the production of material by many contributors, and verify the adequacy and accuracy of the results.

OUTPUTS

Information

Descriptions of the operating system capability for the nontechnical reader

Descriptions of the computer equipment and associated input/output equipment for this program system

Descriptions of the program system that will permit other programmers to maintain the system

Documents

Staff Manual

Technical Operations

Program Maintenance Manual

COSTS

1. Size and complexity of the system.
2. Size and complexity of individual programs.
3. Quality of prior documentation.
4. Number of different manuals to be produced.
5. Number of changes that appear.
6. Number of coordination and review points.
7. Costing formula:

   Drafting rate: 3-5 pages per man day
   Technical review: 20 pages per man day
   Edit: 50 pages per man day
   Revise: 10 pages per man day
   Type: 20 pages per man day
   illustrate: 2 pages per man day

   One may expect 10-35 pages of documentation per 1000 machine instructions.

   At least two drafts (i.e., two iterations of the last steps above) should be expected.

ENVIRONMENT

Resources and Working Conditions

Technical writing, illustrating, and editing capability.

Accurate and complete information on program system operations and system content mandatory.

USER DOCUMENTATION TASK 4

OBTAIN CONCURRENCE ON USER DOCUMENTATION

INPUTS

Information

User documentation requirements

Documents

Concurrence drafts of user documents

SUBTASKS

1. Distribute concurrence drafts to user, Turnover, and other personnel whose concurrence on the user documentation is required.
2. If possible, arrange for trial use of user documents during system tests, user training, and demonstration tests.
3. Arrange, if necessary, to hold a concurrence conference on user documents with the user and other appropriate personnel.
4. Collect commentary, produce revisions, and coordinate the revised drafts with the user, continuing this process until satisfactory documentation is produced.

ENVIRONMENT

Interactions and Dependencies

User and other appropriate personnel, in the review and concurrence on user documentation.

System test and Turnover personnel in the practical evaluation and use of the user documentation.

Dependent upon timely completion of production and coordination of final concurrence draft.

Potential delay in arranging for concurrence conference and in obtaining reviews of the documents by user personnel.

Potential delay in arranging and conducting practical trial use of the documents.

DESCRIPTION

Coordinate the final drafts of user documentation with the user and other appropriate personnel to obtain their approval and concurrence on the documentation, and, if possible, submit the documentation to a practical trial prior to final distribution.

OUTPUTS

Information

Concurrence on user documents

Assurance of adequacy, through practical trials

Documents

Final, concurred-on draft of user documents

COSTS

1. Size and complexity of user documents.
2. Number of review and coordination personnel involved.
3. Number of practical trials attempted.

ENVIRONMENT

Resources

Services of senior technical people are required in the coordination and concurrence conference.

USER DOCUMENTATION TASK 5

PUBLISH USER DOCUMENTATION

INPUTS

Information

Reproduction and format requirements for user documentation

Distribution lists

Schedules

Errors to be corrected

Documents

Concurred-on drafts of user documents

Error reports

SUBTASKS

1. Schedule final production of the user documents.
2. Edit and revise user documents to include features specified during the concurrence proceedings.
3. Incorporate changes and modifications to reflect errors and deficiencies detected during demonstration and shakedown.
4. Perform and coordinate final typing, editing, and reproduction of the documents.
5. Deliver (distribute) the documents to the prescribed distribution list.

ENVIRONMENT

Interactions and Dependencies

Reproduction and distribution facilities, in arranging the final reproduction and distribution of the documents.

Turnover and user personnel, to correct errors and deficiencies in the documents detected during demonstration and shakedown, and to reflect the latest system changes.

Dependent upon the timely completion of the concurrence procedures.

Potential delay in incorporating many system changes.

Potential delay in correcting documentation for errors and deficiencies detected during shakedown.

DESCRIPTION

Produce and distribute the user documents, modified to reflect the latest changes and corrections in the system.

OUTPUTS

Documents

Final copies of user documents

COSTS

1. Number of document changes required to reflect error corrections and system changes.
2. Size of user documentation.
3. Number of copies.
4. Format and degree of polish.
5. Costing formula:

   See Costing formula in User Documentation Task 3. These rates will be accelerated, influenced by the factors above.

ENVIRONMENT

Resources and Working Conditions

Technical writing and editing capability.

Rigorous planning and scheduling to include all last-minute changes and to deliver documents on time.

USER ASSISTANCE TASK 1

ADVISE USER ON DATA COLLECTION AND CONVERSION ACTIVITIES

INPUTS

Information

Data base design

Data requirements

Data gathering and conversion techniques

System design and functional requirements

System environment

Data collection plans, schedules, procedures, forms, and assignments

Data descriptions

Program test data requirements

Data gathering and conversion progress

Documents

Planning Estimate

Project Development Plan

Preliminary Functional Description

Reports on data analysis and analysis of the user's environment

SUBTASKS

1. Inform the user of his data gathering and conversion responsibilities. Assist user to:
   - Evaluate the usefulness of existing data files.
   - Prepare data-gathering forms and procedures.
   - Identify sources of system data.
   - Explain data-gathering requirements to data suppliers.
   - Establish criteria for accuracy and completeness of collected data.
2. Advise user of delays and difficulties likely to be experienced in collecting data from a large number of organizations.
3. Compare the user's data collection plans and schedules, data descriptions, and statement of products with the Project's statements of system requirements, program designs, and schedule deadlines to detect discrepancies.
4. Expedite the clarification and correction of ambiguities and conflicts in descriptions, designs, and schedules, and advise the user and developer on the adequacy of plans.
5. Advise user on the speed, accuracy, and cost of various techniques of converting data, and on establishing procedures for the maintenance of data files, i.e., adding, correcting, and purging data.
6. Coordinate this advice given to the user with other system analysis, design, and development activities, and keep the project informed of the progress of the data-gathering and conversion activities.
7. Assist in obtaining data for program and system tests from the user's data files.
8. Coordinate data base design changes that might arise during either data collection and conversion or program implementation.
9. Assist Turnover personnel in obtaining data for briefings, demonstrations, and training for system users.
10. Evaluate the quality and adequacy of the data base products that the user produces and advise him on their improvement.

ENVIRONMENT

Interactions and Dependencies

User data collection and conversion personnel, on all aspects of their tasks.

Program and system test personnel, on test data requirements and arrangements.

Turnover personnel, on demonstration and training plans and data base needs.

Dependent upon timely delivery of system designs, program and system test plans, implementation and turnover plans.

Potential delay in not getting user to begin data collection and conversion task in time to prepare data files for system testing and/or turnover use.

Potential delay in the review and evaluation of data base products, and in the coordination of data base plans and designs and data base changes.

DESCRIPTION

Inform the user of his responsibilities for the collection and conversion of data, assist him in preparing to collect the data, advise him on the technical aspects of the task and the adequacy of his products, and coordinate and integrate the plans and designs of the system development activity and the user's data collection and conversion activity.

OUTPUTS

Information

Advice to the user on data-collection and conversion techniques

Coordination of data-collection activities with system implementation activities

Arrangements for use of data for program and system test and demonstration purposes

Coordination of data base changes

Assurance of quality in data base products

Arrangements for briefings and other transmissions of information

Documents

Progress reports

Technical memoranda to the user to provide technical advice and assistance

Technical memoranda to the Project to coordinate the details of data base structure and changes thereto

COSTS

1. Degree of knowledge of data base requirements.
2. Level of experience and skill of user in the collection and conversion of data.
3. Degree of close cooperation and rapport with the user.
4. Size and complexity of the system and the associated data base.
5. Degree of knowledge and understanding of user's terminology and environment.
6. Degree of dispersion of data sources, security classification of the data, and other conditions that might create problems of data accessibility.
7. Degree of dependence on sample data from the data base to be used in checkout and turnover.
8. Degree of user recognition of the need to communicate his plans, schedules, and state of progress.
9. Costing formula:

   Part-time job for one analyst, not requiring senior personnel beyond the initial establishment of channels and evaluation of plans.

   Gross estimate: One-quarter time for system analyst for the duration of the project.

ENVIRONMENT

Resources and Working Conditions

Requires the good will and cooperation of user data collection and conversion personnel.

Knowledge of user's terminology and environment.

Knowledge of the system and the impact of data changes upon it.

One system analyst, part time.

Staff and advisory work requires many outside contacts and interactions with Project personnel.

USER ASSISTANCE TASK 2

DEVELOP USER TRAINING PLAN

INPUTS

Information

Details of program system content and operations

Details of user's operational concept and environment

Characteristics of personnel to be trained

Level of training required

Program testing plans

Demonstration test plans

Documents

Plans and schedules

System requirements and design documents

Preliminary Functional Description

Drafts of user documentation

SUBTASKS

1. Review all Project products and documents for the user to determine fully the details of the system and the user's operating concept for the system.
2. Determine the amount of change there will be in the user's operations (i.e., how much the new system differs from the old) and estimate the requirements for training and indoctrination in the use of ADP.
3. Interact and advise the user in determining the extent of the training required, and cooperate with him in the production of a training plan.
4. Determine the characteristics of those to be trained such as present and future duties, level of ADP experience, educational levels, and general level of capabilities.
5. Determine the training requirements necessary to prepare for system testing and demonstration testing.
6. Plan, with the user, a curriculum and schedule that will cover the content and bring the operators and staff up to the required levels of proficiency.
7. Produce and coordinate the training plan with those who will be producing training materials and acting as lecturers and instructors.

ENVIRONMENT

Interactions and Interfaces

Users, on training requirements and advice on the production of the training plan.

Project personnel, to determine system content and system test training requirements and to arrange for materials and teaching assistance.

Dependent upon accurate information on system content and operation and user's operating concept and level of experience.

Potential delay in contacting appropriate and responsible user personnel.

Potential delay in review, coordination, and concurrence upon training plan.

DESCRIPTION

Interact with the user to determine training requirements, and assist him in planning and scheduling training that will help his personnel to adjust to changes in operational concept, and also t prepare for system testing and demonstration testing activities.

OUTPUTS

Information

Training requirements

Coordination of system testing and demonstration activities with training

Assistance to user in planning to train his operators

Documents

Training plans

COSTS

1. Size and complexity of the system.
2. Number of locations where training must be conducted.
3. Level of experience of user personnel in ADP.
4. Number and variety of positions and operators to train for.
5. Level of experience of Project personnel in training and planning to train for a new system.
6. Extent of difference between the operations and activities of the old system and the new.

ENVIRONMENT

Resources and Working Conditions

Normally, senior analysis and design personnel are required for user contacts and training requirements analysis.

Writing, editing, and duplication necessary.

Some educational and training experience.

USER ASSISTANCE TASK 3

CONDUCT TRAINING PROGRAM FOR USER'S STAFF, OPERATORS, AND MAINTENANCE PERSONNEL

INPUTS

Information

Turnover plans

Demonstration test plans

User environment and operations

Total system schedules and plans

User training plans

Availability of space and computer time for required training

System design and operations

Documents

System design documentation

User environment documentation

Schedules

Turnover Plan

Demonstration Test Plan

SUBTASKS

1. Determine characteristics of personnel to be trained such as their organizational units, responsibilities (present and future), and previous ADP experience.
2. Prepare training materials including curricula, briefings and lectures, textual materials, audio-visual displays, and experience with actual equipment.
3. Coordinate classroom requirements and audio-visual support such as projectors and stands.
4. Arrange for the publication and distribution of training manuals and other materials.
5. Conduct classes.
6. Conduct debriefing sessions after the demonstration test.
7. Consult NAVCOSSACT training for personnel for advice and training materials and coordinate training materials with them.

ENVIRONMENT

Interactions and Dependencies

Users on training plans and materials.

NAVCOSSACT training personnel, for advice on training aids and techniques and review of plans.

Project members for subject matter.

Potential delay in determining training needs.

Potential delay in obtaining user cooperation in the preparation of material and the scheduling of classes and demonstrations.

DESCRIPTION

Train user personnel to interpret inputs and outputs, to prepare inputs, to control the computer and program system, and to maintain the program system.

OUTPUTS

Information

Briefings

Lectures

Seminars

Exercises

Training plans

Evaluation of the state of training

Training requirements

Documents

Training aids

Training manuals

Lecture notes

Curricula

Schedules

Status reports

COSTS

1. Size and complexity of system.
2. Number and variety of personnel to be trained.
3. Number of installations to be indoctrinated.
4. Number of lectures and demonstrations delivered.
5. Number of operator positions to prepare material for, volume of inputs each position prepares, number of outputs to interpret, and number of actions that may be taken.
6. Costing formula:

   Estimate ranges from 4 to 16 man weeks.

ENVIRONMENT

Resources and Working Conditions

Knowledge of system and its operation.

Knowledge of user and his operations.

Experience with curriculum development and teaching.

Duplication, graphic arts, technical writing, and other administrative support needed.

TURNOVER TASK 1

DEVELOP THE TURNOVER PLAN

INPUTS

Information

Plans from prior program development activities

Plans from the user data collection and conversion activity

Plans from program testing activity

User requirements for testing, demonstration, and products

Information on user environment

Feedback from user on prior and present plans

Documents

Plans and schedules

System requirements and design documents

Data base design and data definition documents

Implementation Plan

Project Manual (drafts)

Progress reports from prior activities, data collection and conversion, program test

SUBTASKS

1. Document the user's requirements for orientation, training (see User Assistance Task 2), phaseover, and deliverable products.
2. Determine the user's plans for the Demonstration Test (see Turnover Task 2) and coordinate these plans with the personnel that will assist in the Demonstration.
3. Advise the responsible user personnel on turnover and shakedown procedures.
4. Verify schedules for the availability of operational equipment, the data base, and all personnel involved in the Turnover activity.
5. Review and coordinate the drafts of the user documentation and the Turnover Plan with the Turnover personnel.
6. Identify all agencies that will interact during turnover and shakedown and coordinate the Turnover Plan.
7. Assist user personnel in reviewing the Turnover Plan and revise and publish the final version.
8. Prepare the statement of project completion for review and signature.

ENVIRONMENT

Interactions and Dependencies

User on requirements and plans.

Project members on requirements and plans for turnover.

Coordination personnel on Turnover Plan.

Potential delay in contacting appropriate and responsible user personnel.

Potential delay in getting user to formulate Turnover Plan.

Potential delay in coordination, review, and concurrence of Turnover Plan.

DESCRIPTION In cooperation with the user, determine the phaseover requirements from current operations to the new system, including training, orientation, and demonstrations, and prepare plans to satisfy these requirements, including lists of turnover products, needed briefings, training and indoctrination efforts and procedures to demonstrate the successful operation of the system.

OUTPUTS

Information

Turnover requirements

Turnover plans

Assistance to user in turnover planning

Briefings

Documents

Turnover Plan, including delivery schedule for the completed program system and supporting documentation

Coordination memos and letters

COSTS

1. Size and complexity of system.
2. Number of locations to be installed.
3. Level of user experience in ADP.
4. Level of experience and skill of Project personnel for planning and doing turnover tasks.
5. Degree of rapport with user.
6. Number and variety of agencies involved in turnover plans and activities.

ENVIRONMENT

Resources and Working Conditions

Senior personnel required for user contacts.

Writing, editing, and duplication necessary.

Personal contact, analytic ability required.

Intensive contact with user on his plans and requirements.

TURNOVER TASK 2

CONDUCT DEMONSTRATION

INPUTS

Information

Test plans and procedures

Turnover plans

System requirements and design

Demonstration test plans

User environment analysis

Demonstration test designs

User demonstration test requirements

Program test results

Documents

The Turnover Plan

The program system on cards and tape

Scripts, aids, dummy inputs, data base tapes, and other materials

System requirements and design documents

Program test plans, requirements, and design documents

Drafts of user documentation

SUBTASKS

1. Identify user personnel responsible for demonstration and estimate level of system knowledge and experience in system testing.
2. Provide documents on system test design, sample tests, and test results to user personnel.
3. Review user plans and schedules for the demonstration test (see Turnover Task 1).
4. Produce or assist in the production of system test material required for the demonstration test.
5. Brief the participating personnel on the objectives and procedures of the demonstration.
6. Dry run the entire test if time permits.
7. Conduct the test and document the results.
8. Debrief the personnel that attended and participated in the demonstrations.

ENVIRONMENT

Interactions and Dependencies

User on demonstration plans and assistance.

Project personnel on participation in tests.

Dependent upon successful and timely completion of system tests.

Potential delay in making final arrangements with user.

DESCRIPTION

Prepare for and conduct the demonstration test of the system jointly with user personnel.

OUTPUTS

<u>Information</u>

Briefings

Final preparations and plans

Debriefings

<u>Documents</u>

Detailed schedule

Reports on demonstration results

COSTS

1. Size and complexity of system to be tested.
2. Number and extent of demonstration tests to be run.
3. Level of experience of user personnel in conducting system tests and applying ADP to their operations.
4. Costing Formula:

   Final preparation and actual conduct of the test for a system of moderate size should take an elapsed time of about one week. One or more dry runs, especially if associated with operator training, may add one or more weeks to the schedule.

   Estimate about two man weeks for system of about 10,000 to 20,000 instructions.

ENVIRONMENT

<u>Resources and Working Conditions</u>

Requires skill in personal relations.

Knowledge of user's operation and ability to understand user's point of view.

Experience and skill in system test techniques.

TURNOVER TASK 3

ASSIST IN THE OPERATIONAL SHAKEDOWN OF THE SYSTEM

INPUTS

__Information__

Detailed knowledge of the program system

Detailed knowledge of user's operation and environment

Knowledge of program tests and test requirements

__Documents__

Program specifications

Preliminary Functional Description

User documentation

Program and system test plans and results

SUBTASKS

1. Monitor the initial period of operation of the system to detect malfunctions and inefficiencies and to evaluate the performance of the system.

2. Interact with operational personnel to give advice, answer questions, and clarify errors and misconceptions concerning the system.

*3. Establish procedures for reporting suspected program malfunctions, including the details of what and to whom to report.

4. Receive and investigate reports of program malfunctions from the user. determine the precise conditions surrounding the suspected malfunction and whether the malfunction is due to a program error, an operator error, an equipment failure, or a misunderstood specification.

5. Transmit reports of malfunctions suspected of being a program error to the responsible programmers, along with as much supporting evidence and surrounding details as possible, for a more searching diagnostic run.

6. Identify reported malfunctions as either:

   a. an error in programming, that is, the requirements were understood, but incorrectly implemented; or,

   b. an error in logic, that is, the requirements were not understood, and therefore were incorrectly implemented.

7. Estimate the cost of making the necessary changes and coordinate a plan for implementing the changes with NAVCOSSACT management and the user.

8. Install, test, and further shakedown any modifications to the program made during the shakedown period as a result of design change requests, and correction of errors.

*Steps 3 through 8 constitute a typical procedure for handling errors after initiation of shakedown.

ENVIRONMENT

__Interactions and Dependencies__

Operational personnel, in giving advice and monitoring the operation of the system.

User personnel, in reviewing and evaluating suspected malfunctions.

Project personnel, in correcting errors and in processing requests for major changes.

Dependent upon the quality of the debugging and testing achieved, and degree of adherence to system specifications.

Potential delays in educating operators to distinguish between their own and program errors.

Potential delay in transmitting reports of malfunctions to programmers and getting corrections made and checked out.

DESCRIPTION

Monitor the operation of the system during the shakedown period to detect and correct malfunctions in the programs, and to assist the user in learning to use and understand the system.

OUTPUTS

<u>Information</u>

Detected malfunctions

Operator training

Procedures for reporting and correcting malfunctions

Improved customer relations

<u>Documents</u>

Reports of suspected malfunctions

Design change requests

Agreements on the handling of system modifications

COSTS

1. Size and complexity of system.
2. Quality of delivered system and documentation.
3. Level of operator training.
4. Degree of change from prior operations.
5. Number of locations involved in shakedown.

ENVIRONMENT

<u>Resources and Working Conditions</u>

Detailed knowledge of system operations and user's environment.

Skill in personal relations.

Skill in detecting and correcting program malfunctions.

Many contacts with user and system operators.

Shakedown is a period of considerable anxiety and uncertainty as operators learn to use the system and as errors are detected, not only in the programs, but in procedures and equipment.

Period likely to be one of recurring emergencies and conferences to seek solutions to problems and misunderstandings.

PROJECT SUMMARY SHEET **PROJECT ID**

REQUEST CODE	DATE	REQUEST TITLE	REQUESTING

DIVISION	PROJECT LEADER	DATE ASS D.	CONTRACTOR

PROJECT D

MISSION AND OBJECTIVES

USING ORGANIZATIONS AND PLACEMENT

PRIMARY FUNCTIONS

SYSTEM EN

SYSTEM NAME	PROJECT NO	USING ORG
1. EMBEDDING SYSTEMS		
2. INTERFACING SYSTEMS		
3. SIMILAR SYSTEMS		

MANNING ASSUMPTIONS KEY PERSONNEL	LEAD TIME A

COMPUTI

COMPUTER	LOCATION	OPERATING SYSTEM	LANGUAGE	DATE OF FIRST USE	TOTAL EST

NUMBER OF COMPU

FIRST ESTIMATE (PE RELEASE) SECOND ESTIMATE (PDP RELEASE) THIRD ESTIMATE (PFD RELEASE)

MMARY SHEET

}E 2)

NUMBER OF COMPUTER HRS.		PROPOSED MANNING				REMARKS (DATES AND REASONS FOR REVISIONS, ETC.)
EST	ACT	SR. ANAL	ANAL	SR. PROG	PROG	

ENTIFICATION

; ORGANIZATION		REFERENCES REQUESTING LETTER	PREPARED BY
	CONTRACT DATE	OTHER	REVIEWED BY APPROVED BY

ESCRIPTION

IVIRONMENT

ANIZATION	NATURE OF APPLICATION

SSUMPTIONS

CONTACTS

USER

CONTRACTOR

EQUIPMENT

OTHER

ER USAGE

HOURS	MAXIMUM USAGE			TURNAROUND TIME	COMMENTS
ACT	HRS/DAY	HRS/WEEK	HRS/PERSON		

JTER INSTRUCTIONS

ACTUAL (SOURCE LANGUAGE)

ACTUAL (MACHINE LANGUAGE)

PROJECT SU
(PA

PROJECT PHASES & TASKS	NUMBER OF MAN MONTHS			START DATE			COMPLETION DATE		
	EST	REV EST	ACT	EST	REV EST	ACT	EST	REV EST	A
SYSTEM ANALYSIS 1. PLAN THE PROJECT									
2. ANALYZE SYSTEM REQUIREMENTS									
3. ANALYZE USER ENVIRONMENT									
4. ANALYZE PRODUCTION REQUIREMENTS									
5. ANALYZE SIMILAR SYSTEMS									
6. EVALUATE CONTRACT PROPOSALS									
7. ANALYZE CHANGE REQUESTS									
SYSTEM DESIGN 1. DESIGN TOTAL SYSTEM									
2. DESIGN PROGRAM SYSTEM									
3. OUTLINE PRELIMINARY FUNCTIONAL DESCR.									
4. PRODUCE PRELIMINARY FUNCTIONAL DESCR.									
5. FAMILIARIZE USER									
6. OBTAIN PFD CONCURRENCE									
7. INDOCTRINATE PRODUCTION PERSONNEL									
	★		★		★		★		★
PROGRAM DEVELOPMENT 1. DESIGN PROGRAM SYSTEM TEST									
2. DESIGN PROGRAMS									
3. DESIGN PROGRAM FILES									
4. ESTABLISH SYSTEM FILES									
PROGRAM CODING 1. CODE PROGRAMS									
2. DESK CHECK PROGRAMS									
PROGRAM CHECKOUT 1. LEARN TEST ENVIRONMENT									
2. COMPILE AND CHECK CODE									
3. TEST PROGRAMS									
4. TEST SUBSYSTEMS									
5. TEST SYSTEM									
USER DOCUMENTATION 1. VERIFY SPECIFICATION DOCUMENTATION									
2. OUTLINE USER DOCUMENTATION									
3. PRODUCE USER DOCUMENTATION									
4. OBTAIN CONCURRENCE									
5. PUBLISH USER DOCUMENTATION									
USER TRAINING AND ASSISTANCE 1. DATA COLLECTION AND CONVERSION									
2. DEVELOP USER TRAINING PLAN									
3. PROVIDE USER TRAINING AND ASSISTANCE									
TURNOVER 1. DEVELOP TURNOVER PLAN									
2. CONDUCT DEMONSTRATION									
3. OPERATIONAL SHAKEDOWN									
TOTALS									

★ PHASES ABOVE THIS LINE WILL BE COMPLETED AFTER PLANNING ESTIMATE IS APPROVED.

PHASES BELOW THIS LINE WILL BE COMPLETED AFTER PRELIMINARY FUNCTIONAL DESCRIPTION IS APPROVED.

ENTIFICATION

ORGANIZATION		REFERENCES REQUESTING LETTER	PREPARED BY
	CONTRACT DATE	OTHER	REVIEWED BY APPROVED BY

ESCRIPTION

IVIRONMENT

ANIZATION	NATURE OF APPLICATION

SSUMPTIONS

CONTACTS

	USER
	CONTRACTOR
	EQUIPMENT
	OTHER

ER USAGE

HOURS ACT	MAXIMUM USAGE HRS/DAY	HRS/WEEK	HRS/PERSON	TURNAROUND TIME	COMMENTS

JTER INSTRUCTIONS

ACTUAL (SOURCE LANGUAGE)

ACTUAL (MACHINE LANGUAGE)

COMPUTER PROGRAM

PROGRAM IDENTIFICATION	PROGRAM NAME	PRO

PROGRAM DEVELOPMENT

PROGRAM DESIGN	MAN MONTHS			START DATE			END D	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E
LOGIC ANALYSIS & FLOW CHART								
TIMING ANALYSIS								
DESIGN REVIEW								
PROGRAM SPECIFICATIONS								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 2						ELAPSED TIME		

DATA DESCRIPTION	NUMBER OF ITEMS			INPUT FORMATS			OUTPUT F	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E

DATA DESIGN	MAN MONTHS			START DATE			END D	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E
DATA ANALYSIS								
I/O FORMATS								
DATA DESIGN								
ALLOCATE STORAGE								
DATA REVIEW								
DOCUMENTATION								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 3						ELAPSED TIME		

PROGRAM DESCRIPTION	NUMBER OF INSTRUCTIONS						NUMBER OF	
		NEW			REVISED			
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E
ENTER TOTAL NUMBER OF INSTRUCTIONS ON SUMMARY SHEET								

PROGRAM CODING

CODING DESCRIPTION	NEW ROUTINES			REVISED ROUTINES			LIBRARY R	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E

CODING	MAN MONTHS			KEY PUNCH & VERIFY MACH. HRS.			START	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E
CODE								
DESK CHECK								
DOCUMENT								
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CODING TASK 1 AND 2								

PROGRAM CHECKOUT

CHECKOUT DESCRIPTION	NUMBER COMPILE ASSY.			NUMBER CODE CHECKS			TEST	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E

	MAN MONTHS			START DATE			COMPLETIO	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E
COMPILE AND CHECK CODE								
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 2								
DESIGN PROGRAM TEST								
TEST DATA PRODUCTION								
TEST PROGRAM								
TOTAL AND ENTER ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 3								

REMARKS

PREPARED BY	REVIEWED BY

PLANNING SHEET

AM FUNCTION	TYPE JOB (NEW, CONVERSION, REV.)

E	ASSIGNMENTS	
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RMATS	NUMBER OF TABLES			NO. OF CONSTANTS & PARAMETERS			NUMBER OF FILES		
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NUMBER OF PROGRAM TESTS				NUMBER PAGES OF DOCUMENTS			
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ACTUAL	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	

DATE	NO. OF COMPUTER HRS.		ASSIGNMENTS
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COMPUTER PROGRAM F

PROGRAM IDENTIFICATION	PROGRAM NAME	PROGRAM

PROGRAM DEVELOPMENT

PROGRAM DESIGN	MAN MONTHS			START DATE			END DATE	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST
LOGIC ANALYSIS & FLOW CHART								
TIMING ANALYSIS								
DESIGN REVIEW								
PROGRAM SPECIFICATIONS								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 2						ELAPSED TIME		

DATA DESCRIPTION	NUMBER OF ITEMS			INPUT FORMATS			OUTPUT FORM.	
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DATA DESIGN	MAN MONTHS			START DATE			END DATE	
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DATA ANALYSIS								
I/O FORMATS								
DATA DESIGN								
ALLOCATE STORAGE								
DATA REVIEW								
DOCUMENTATION								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 3						ELAPSED TIME		

PROGRAM DESCRIPTION	NUMBER OF INSTRUCTIONS						NUMBER OF BL	
		NEW			REVISED			
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST
ENTER TOTAL NUMBER OF INSTRUCTIONS ON SUMMARY SHEET								

PROGRAM CODING

CODING DESCRIPTION	NEW ROUTINES			REVISED ROUTINES			LIBRARY ROUT	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST

CODING	MAN MONTHS			KEY PUNCH & VERIFY MACH. HRS.			START DATE	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST
CODE								
DESK CHECK								
DOCUMENT								
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CODING TASK 1 AND 2								

PROGRAM CHECKOUT

CHECKOUT DESCRIPTION	NUMBER COMPILE ASSY.			NUMBER CODE CHECKS			N	
								TESTS
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV EST

	MAN MONTHS			START DATE			COMPLETION D	
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COMPILE AND CHECK CODE								
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 2								
DESIGN PROGRAM TEST								
TEST DATA PRODUCTION								
TEST PROGRAM								
TOTAL AND ENTER ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 3								

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FUNCTION	TYPE JOB (NEW, CONVERSION, REV.)

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ACTUAL	FIRST	SECOND

ATS	NUMBER OF TABLES			NO. OF CONSTANTS & PARAMETERS			NUMBER OF FILES		
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	TRIALS						
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ATE	NO. OF COMPUTER HRS.		ASSIGNMENTS
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COMPUTER PROGRAM

PROGRAM IDENTIFICATION	PROGRAM NAME	PROGRA

PROGRAM DEVELOPMENT

PROGRAM DESIGN	MAN MONTHS			START DATE			END DATE	
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LOGIC ANALYSIS & FLOW CHART								
TIMING ANALYSIS								
DESIGN REVIEW								
PROGRAM SPECIFICATIONS								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 2						ELAPSED TIME		

DATA DESCRIPTION	NUMBER OF ITEMS			INPUT FORMATS			OUTPUT FORM	
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DATA REVIEW								
DOCUMENTATION								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 3						ELAPSED TIME		

PROGRAM DESCRIPTION	NUMBER OF INSTRUCTIONS						NUMBER OF BL	
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PROGRAM CODING

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ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CODING TASK 1 AND 2								

PROGRAM CHECKOUT

CHECKOUT DESCRIPTION	NUMBER COMPILE ASSY.			NUMBER CODE CHECKS			N	
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COMPILE AND CHECK CODE								
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 2								
DESIGN PROGRAM TEST								
TEST DATA PRODUCTION								
TEST PROGRAM								
TOTAL AND ENTER ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 3								

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FUNCTION	TYPE JOB (NEW, CONVERSION, REV.)

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ACTUAL	FIRST	SECOND

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COMPUTER PROGRAM

PROGRAM IDENTIFICATION	PROGRAM NAME	PROGR

PROGRAM DEVELOPMENT

PROGRAM DESIGN	MAN MONTHS			START DATE			END DAT	
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LOGIC ANALYSIS & FLOW CHART								
TIMING ANALYSIS								
DESIGN REVIEW								
PROGRAM SPECIFICATIONS								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 2						ELAPSED TIME		

DATA DESCRIPTION	NUMBER OF ITEMS			INPUT FORMATS			OUTPUT FOR	
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DATA ANALYSIS								
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DATA REVIEW								
DOCUMENTATION								
TOTAL AND ENTER ON SUMMARY SHEET PROGRAM DEVELOPMENT TASK 3						ELAPSED TIME		

PROGRAM DESCRIPTION	NUMBER OF INSTRUCTIONS						NUMBER OF B	
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PROGRAM CODING

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CODE								
DESK CHECK								
DOCUMENT								
ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CODING TASK 1 AND 2								

PROGRAM CHECKOUT

CHECKOUT DESCRIPTION	NUMBER COMPILE ASSY.			NUMBER CODE CHECKS			TESTS	
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ENTER TOTALS ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 2								
DESIGN PROGRAM TEST								
TEST DATA PRODUCTION								
TEST PROGRAM								
TOTAL AND ENTER ON SUMMARY SHEET FOR PROGRAM CHECKOUT TASK 3								

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.M FUNCTION	TYPE JOB (NEW, CONVERSION, REV.)

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ELAPSED TIME					

NUMBER OF PROGRAM TESTS	TRIALS			NUMBER PAGES OF DOCUMENTS			
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DATE	NO. OF COMPUTER HRS.		ASSIGNMENTS
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PROGRAM SYSTEM F

SYSTEM CHECKOUT DESCRIPTION	NUMBER OF SUBSYSTEM TESTS							
	TESTS			TRIALS			TEST	
	EST	REV EST	ACTUAL	EST	REV EST	ACTUAL	EST	REV E

PROGRAM SUBSYSTEM TESTS	MAN MONTHS			START DATE			COMPLETIC	
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DESIGN SUBSYSTEM TEST								
TEST DATA PRODUCTION								
TEST SUBSYSTEM								
TOTAL AND ENTER ON SUMMARY SHEET, PROGRAM CHECKOUT, TASK 4					ELAPSED TIME			

PROGRAM SYSTEM TESTS								
DESIGN SYSTEM TEST								
TEST DATA PRODUCTION								
TEST PROGRAM SYSTEM								
TOTAL AND ENTER ON SYMMARY SHEET, PROGRAM CHECKOUT, TASK 5					ELAPSED TIME			

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NUMBER OF SYSTEM TESTS				
		TRIALS		
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1. ORIGINATING ACTIVITY (Corporate author) System Development Corporation, Santa Monica, Calif.	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP
3. REPORT TITLE PLANNING GUIDE FOR COMPUTER PROGRAM DEVELOPMENT.	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)	
5. AUTHOR(S) (Last name, first name, initial) Farr, L., LaBolle, V., and Willmorth, N. E.	
6. REPORT DATE 10 May 1965	7a. TOTAL NO. OF PAGES 179p. / 7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. Nonr 4543(00)	9a. ORIGINATOR'S REPORT NUMBER(S) TM-2314
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	
10. AVAILABILITY/LIMITATION NOTICES	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

This document offers a systematic approach for planning projects to develop computer-based information systems. The primary emphasis is placed on the computer program portion of such systems. A descriptive model of the development process forms the basis for a set of prescribed planning and management tasks. The model includes eight phases: (1) System Analysis, (2) System Design, (3) Program Development, (4) Program Coding, (5) Program Checkout, (6) User Documentation, (7) User Training and Assistance, and (8) Turnover. Each phase is further divided into tasks and subtasks for the purpose of more clearly understanding the elements of the development process. A detailed sequence of planning activities provides guidance for planning, scheduling and costing the tasks that comprise the development process, and forms are supplied to record the planning results and to serve as checklists for the required work. The forms and procedures also provide a basis for project control and for collection of data that may be used to improve estimates based upon experience. Although this Guide was prepared for use at the Naval Command Systems Support Activity, the material can easily be adapted to apply to programming in other organizations. (authors)

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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